



GROUND SOURCE HEAT PUMP WORKSHOP

"The Opportunity for Ontario"

**January 10, 1985
Airport Holiday Inn
TORONTO**

PROCEEDINGS



**Ministry of
Industry
and
Trade**



**Ministry
of
Energy**

GROUND SOURCE HEAT PUMP WORKSHOP

"The Opportunity for Ontario"

January 10, 1985 - Airport Holiday Inn, Toronto

"A Futuristic Concept — or a
Realistic Technology for Application
in Ontario"

PROCEEDINGS

SPONSORED BY:

ONTARIO HYDRO RESEARCH DIVISION, THE MINISTRY
OF INDUSTRY & TRADE AND THE MINISTRY OF
ENERGY IN COOPERATION WITH THE CONSULTING
ENGINEERS OF ONTARIO, THE ELECTRICAL AND
ELECTRONIC MANUFACTURERS ASSOCIATION OF
CANADA, THE HEATING, REFRIGERATION AND AIR
CONDITIONING INSTITUTE, ASHRAE - TORONTO,
ONTARIO ELECTRICAL LEAGUE.

FOR FURTHER INFORMATION:

N.D. MARKETOS
MINISTRY
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965-3478

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965-3560

F. LENARDUZZI
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231-4111
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GROUND SOURCE HEAT PUMP WORKSHOP

"THE OPPORTUNITY FOR ONTARIO"

January 10, 1985 - Airport Holiday Inn, Toronto

8:00 a.m. REGISTRATION

8:30 a.m. WELCOME ADDRESS

Bruce MacOdrum
Assistant Deputy Minister
Ontario Ministry of Energy

TECHNOLOGY OVERVIEW OF GROUND SOURCE SYSTEMS

Moderator: N.D. Marketos
Ministry of Energy

Developments and Utilization

Prof. J.D. Parker
Oklahoma State University, U.S.A.

Applications In Sweden

J.G. Oskarsson
Swedish Association of Heat Pump
Manufacturers

Engineering for Best Performance

F. Hooper, Hooper and Angus,
Consulting Engineers, Toronto

10:00 a.m. COFFEE

10:20 a.m. GROUND COUPLED SYSTEMS

Moderator: J.M. Bell
Ontario Hydro

Systems Suited for Urban Use

S.G. Oskarsson, Cantherm Heating,
Montreal

Installing Heat Pick-Up Systems

F. Murphy, President, Toronto
Chapter, HRAI, Toronto

GROUND COUPLED SYSTEMS (CONTINUED)

Geological Considerations in Ontario
and How Much Heat Can Be Used

J. Phimister, Gartner, Lee and
Associates, Ltd., Toronto

Systems and Developments

O. Svec, National Research Council,
Ottawa

DRILLING FOR HEAT - THE PRACTICAL ASPECTS

Moderator: D. Cane
Ontario Research Foundation,
Mississauga

C.B.H. Cragg, Ontario Hydro, Research
P. Albertson, The Charles Machine Works
H.S. Radhakrishna, Ontario Hydro Research
A. Gustafsson, Atlas Copco Energy Ab.

12:30 p.m. LUNCH

Luncheon Speaker

William Sande, Vice President
Corporate Development and Technology
Imperial Oil

2:00 p.m. APPLICATIONS AND OPPORTUNITIES

Moderator: D.J. Young
Ontario Hydro

Monitoring and Results from Operating Systems

F.J. Lenarduzzi
Ontario Hydro, Research

Opportunities in Agriculture

H. Spieser, Ridgetown College of
Agriculture Technology, Ridgetown, Ontario

Applications in Industry

D.L. Hatherton
Water Furnace International

APPLICATIONS AND OPPORTUNITIES (CONTINUED)

The Economics of Ground Coupled Systems

G. DiRezze, Villeneuve Limited,
Toronto

3:10 p.m. COFFEE

3:30 p.m. OPTIONS, IMPLEMENTATION AND STRATEGIES

Moderator: W.A. Ledingham
Ministry of Industry
and Trade

G. Vandervaart
Kool-Fire, Niagara Falls

A.C. Bierbaum, Iowa Association
of Electric Cooperatives, Iowa, U.S.A.

M. Dyke
North York Hydro

CLOSING REMARKS

D.B. McCarthy
Vice President, Marketing
Ontario Hydro

Sponsored by: Ontario Hydro Research Division, The Ministry of Industry & Trade and The Ministry of Energy in cooperation with The Consulting Engineers of Ontario, The Electrical and Electronic Manufacturers Association of Canada, The Heating, Refrigeration and Air Conditioning Institute, ASHRAE - Toronto, Ontario Electrical League.

IN AN EFFORT TO PRODUCE THE PROCEEDINGS

IN THE MINIMUM AMOUNT OF TIME,

SOME OMISSIONS MAY HAVE OCCURRED.

PAPERS ARE AS SUBMITTED BY THE AUTHORS.

SPEAKING NOTES FOR
I. BRUCE MACODRUM, QC
ASSISTANT DEPUTY MINISTER OF ENERGY
ENERGY POLICY AND PLANNING

WELCOME ADDRESS
TO
GROUND SOURCE HEAT PUMP WORKSHOP

AIRPORT HOLIDAY INN
970 DIXON ROAD
FIESTA BALLROOM

JANUARY 10, 1985
8:30 A.M.

Good morning. I'm pleased to welcome you to this workshop. And, I must say, I am pleased to see such a large audience (400).

When this workshop was planned, we didn't expect that "ground source heat pumps" would have the popular appeal of Michael Jackson. But we were surprised -- this event has been a "sell-out". Registration had to be closed because we didn't have enough space to seat all the people who wished to attend.

Perhaps the attendance level makes an important point -- that ground source heat pumps are becoming recognized for what they are -- an exciting new technology with a great deal of promise.

As the theme of the workshop states, this technology represents an "Opportunity for Ontario".

In terms of operating costs, ground source heat pumps are one of the least expensive ways to heat and cool buildings. As well, they have other merits -- they are an efficient use of electricity and can reduce seasonal fluctuations on electrical demand.

Despite the merits, commercialization has been slower than the Ministry of Energy hoped. The heart of the problem -- in a nutshell -- is that installation is expensive. Specifically, it's a matter of drilling the hole -- we need to determine ways to reduce costs and simplify methods of drilling holes. And, that is the objective of this workshop.

I'd like to stress, at this point, that it is not only the Ministry of Energy which recognizes the merits of ground source heat pumps. This workshop illustrates that point. It was sponsored and organized with the support of many interested parties.

Both Ontario Hydro and the Ontario Ministry of Industry and Trade joined with the Ministry of Energy as sponsors. As well -- and I feel this is particularly significant -- the workshop was organized with a great deal of help and cooperation from several associations representing the private sector.

I would like to thank the following associations for their assistance in organizing this excellent workshop:

The Consulting Engineers of Ontario
The Electrical and Electronic Manufacturers Association of
Canada
The Heating, Refrigeration and Air Conditioning Institute
ASHRAE
and, The Ontario Electrical League.

I would like to emphasize that this spirit -- the idea of government and the private sector working hand in hand toward a mutual goal -- reflects an extremely important concept. In the Ontario government today -- and within the Ministry of Energy -- there is a great emphasis on the importance of working with the private sector in order to pursue common goals of mutual benefit.

The Ministry of Energy's support of ground source heat pumps reflects this approach. The first question we must ask is: How can ground source heat pumps benefit Ontario?

The answer is simple: Ground source heat pumps are one of many electrotechnologies which have the potential to greatly increase energy efficiency. The Province of Ontario has a stated commitment to furthering the development of electrotechnology.

This commitment was stated by the Board of Industrial Leadership Development, or BILD, in January, 1981. The BILD commitment is this:

"The province's electrical system will be utilized whenever practical to substitute for oil consumption, thereby complementing national and global off-oil initiatives. This strategy will obtain massive economic benefits from substituting an indigenous energy source for petroleum, will provide greater energy security for Ontario's economic future and will keep Ontario in the forefront of electrical power technology."

The Province's commitment was re-emphasized in the Throne Speech, March 1984. The Province of Ontario and the Ministry of Energy are committed to the further development of electrotechnology for several reasons:

- to make better use of an indigenous energy source
- to make Ontario industry more efficient and competitive
- and, as an outgrowth of increased competitiveness, to create more jobs in Ontario.

The Province's position is very much in keeping with the industry's position. In October, 1984, a Joint Industry Task Force report was presented to the Premier. The Task Force presented a well thought out report with many specific recommendations which are currently being reviewed by the government.

The members of the Task Force represented a large segment of the industry including the associations which helped organize this workshop. The main thrust of the report was that Ontario must work toward building an internationally competitive electrical industry.

Today, both the Ministry of Energy and the industry are working together to encourage the development of electrotechnology. Certainly, this workshop is one example, but there are many more.

In terms of specific support of ground source heat pumps, the Ministry of Energy, in conjunction with the federal government, is supporting 3 projects in Ontario which have been installed and are being monitored.

One project is Arc Rental, a company which assembles welding equipment for sale and rental. George Inward, the President, has had two heat pumps installed to provide space heating and passive cooling to his building.

Funding:

Arc Rental Service Limited	\$39,841
Ministry of Energy	\$24,500
Energy, Mines and Resources Canada	\$24,500

Another is Queen's Quay, a lakeshore warehouse that Olympia and York real estate developers modified into luxury condominiums, office spaces and retail stores. Heat pumps contribute to the heating and cooling of stores and offices using water from the Toronto Harbour.

Funding:

Olympia and York Developers	\$318,000
Ministry of Energy	\$100,000
Energy, Mines and Resources Canada	\$100,000

Valley East is a community of 20,000 people north of Sudbury which constructed a \$2.5 million recreation complex. Heating, cooling and dehumidification are primarily supplied by a heat pump/heat exchanger system connected to ground water wells.

Funding:

Town of Valley East	\$205,503
Ministry of Energy	\$165,439
Energy, Mines and Resources Canada	\$165,439

When the reports are compiled on these projects, the data will be very helpful in assessing the economic feasibility of ground source heat pumps. Yet, even without the reports, we know that it is imperative to reduce the capital installation costs if these systems are to be economically feasible. In that regard, I'm very pleased to announce that the Ministry of Energy has agreed to support a new research project with the Ontario Hydro Research Division.

The Ministry will pay for 50 per cent of the cost to help fund a project to assess the feasibility and field testing of a variety of ground source heat pump drilling techniques. The objective is to determine ways to reduce the installation costs of these systems.

In recent years, the Ministry of Energy has contributed significantly toward the development of ground source heat pumps and will continue to do so.

The energy climate has changed in the past decade and our recent reorganization was in response to these new realities. For example, we have strengthened and solidified our electrotechnology effort. The Ministry's commitment to electrotechnology is outlined in a new brochure, "The Electro-Technology Opportunity". It was just printed this week and is available at this workshop.

If I may digress for just a moment, I'd like to make a comment on the role of the Ministry of Energy as it relates to the role of the private sector. In this regard, I'm speaking specifically about the development of new technology which has the potential to increase energy efficiency and benefit Ontario.

Our main role -- our most important function -- is to be a catalyst. We allocate funds to support research, to encourage the development of new technology, and to demonstrate the commercial viability of promising technologies. And, once we have done so, it is the role of the private sector to pick up the ball and run.

Government initiatives can help create a greater awareness of technological development and identify potential opportunities, but the private sector must also play a role. The private sector should aggressively pursue and create commercially viable projects which will help keep Ontario in the forefront of new achievements in electrotechnology.

The purpose of this workshop is to stimulate ideas and act as a catalyst for the continued development of ground source heat pumps. As the theme of the workshop states, they represent an "Opportunity for Ontario".

Thank you.

SPEAKING NOTES FOR
JERALD D. PARKER, P.E., PH.D.
PROFESSOR OF MECHANICAL ENGINEERING
OKLAHOMA STATE UNIVERSITY
STILLWATER, OK 74078

TECHNOLOGY OVERVIEW
OF GROUND SOURCE SYSTEMS
- DEVELOPMENTS AND UTILIZATION

AIRPORT HOLIDAY INN
970 DIXON ROAD
FIESTA BALLROOM

JANUARY 10, 1985
8:30 A.M.

Professor J.D. Parker

Dr. Jerald Parker is a graduate of Oklahoma State University, and Purdue, and is Professor of Mechanical Engineering at Oklahoma State. Co-author of textbooks on "Fluid mechanics and heat transfer," and "Heating and ventilating and air conditioning," he is active in a number of technical societies and acts as a consultant to government agencies and industry.

Air source heat pumps have been growing in popularity for about three decades, promoted by utility companies seeking additional energy sales and hoping to level their demand curves over an annual cycle. Several books on heat pumps have been written recently (1), (2), (3), (4), (5).

The growth in air-to-air heat pump shipments in the U.S. since 1976 can be seen in Figure 1, taken from Reference (5). The upward surge in the late 70's was due to gas curtailments, the downward plunges in 1980 and 1982 were due mainly to new home construction. There were 629,800 units shipped in 1983 and a 7 per cent increase to about 675,000 units was anticipated for 1984. Shipments of water source heat pumps in the U.S. have risen steadily from 40,000 units in 1977 to an anticipated 102,500 units in 1984. In referring to water source heat pumps used in ground coupling the News article stated, "It is in this . . . application, which uses ground heat rather than ground water and can be applied in urban areas, which shows the most promise for growth" (6).

The ground source heat pump has several advantages over the air source heat pump including no outside unit and no defrost problems. In addition the close temperature approach permitted in water-refrigerant heat exchangers (compared to air-refrigerant exchangers) permits lower differences between the condenser and evaporator. This leads, in most cases, to improved COP's and seasonal performance factors for the ground coupled system.

Interest in ground coupled systems began at Oklahoma State University in studies on solar assisted heat pump systems. Large, uninsulated, buried tanks were conceived to be a way to assist the heat pumps in energy storage, and a way to provide extra storage by contact with the earth.

It did not take long to see that the "best" system was a tank with large surface-to-volume ration, i.e., a long, thin tank, or pipe. Interest in the solar aspects waned when it was realized that energy could be obtained more easily (more economically) from the ground than from collectors.

The basic heat transfer process in a ground exchanger is shown in Figure 2, for the heating season. Cooled water, or brine, discharged from the evaporator of the heat pump, is passed through the ground exchanger, increasing in temperature from T_1 as it receives heat from the ground. In the limit, for a very long tube or tubes, the liquid can be brought back only to the undisturbed ground temperature. In actual practice there will be a depression in the ground temperature around the pipe as the season progresses, and there must also be a finite terminal temperature difference or approach. As a result the temperature T_2 , returning to the heat pump evaporator, may be very much less than the undisturbed ground temperature, and for climates such as Canada the liquid may fall below the freezing point of water.

Ground exchangers may be of the vertical or horizontal type, Figure 3. The horizontal type, may in turn be either a series or parallel arrangement, Figures 4 and 5. Horizontal systems are affected by seasonal variations in ground temperature. This variation with depth is shown for three types of soil in Figure 6. The seasonal variation at several depths for one type of soil is shown in Figure 7. The ground-coupled heat pump affects this normal variation by raising the local ground temperature during the cooling season, or depressing it during the heating season, Figure 8.

Vertical systems avoid this seasonal change to a significant extent and also permit a large portion of the exchanger to be below the natural water table, where thermal conductivity values of the soil will usually be high. The annular vertical system shown in Figure 9 was very popular in early installations in Oklahoma. In recent times the U-tube installation, shown in Figure 2, has become popular. These are usually installed with 3/4 inch to 1 1/2 inch polyethylene or polybutylene pipe, and may be placed in multiple holes as shown in Figure 10 for a series system and Figure 11 for a parallel system. There are a large number of these systems installed in the United States including multiple systems for apartments and commercial buildings.

Economics is, of course, an important controlling factor in sizing the ground exchanger. The typical problem is to determine the amount and quality of system to install to minimize life cycle cost, Figure 12. One study at Oklahoma State University has been an attempt to determine the optimum type of vertical exchanger to install. Figure 13 shows five types of vertical exchangers that were studied.

Computer simulations are useful in determining the performance of ground-coupled systems. The logic involved in a typical simulation is shown in Figure 14.

Thermal properties of the ground, particularly resistivity, are very important to the performance and design of ground coupled systems. How resistivity can vary with soil type and moisture is shown in Figure 15.

Variations in soil properties caused by freezing would be an important consideration in northern climates such as in Canada.

A design data manual for ground coupled heat pumps is being written at Oklahoma State University under the sponsoring of ASHRAE. This manual will give many references, useful design data, and will discuss design methods. Copies of the manual will likely become available sometime in 1985. Because of rapidly developing knowledge and changing techniques, it is expected that the manual will be revised as needed.

REFERENCES

1. D. A. Reay and D.B.A. MacMichael, Heat Pumps, Design and Applications, Pergamon Press, 1979.
2. Norman W. Lord, et. al., Electrotechnology Volume 4, Heat Pump Technology, Ann Arbor Science Publishers, 1980.
3. R.D. Heap, Heat Pumps, Halsted Press Book, John Wiley & Sons, 1979.
4. J.F. McMullan and R. Morgan, Heat Pumps, Adam Hilger, Ltd., 1981.
5. Harry J. Saver, Jr. and Ronald H. Howell, Heat Pump Systems, Wiley Interscience, 1983.
6. Air Conditioning, Heating and Refrigeration News, April 2, 1984, Business News Publishing Co., Troy, Michigan.
7. J.E. Bose, Water Source HVAC Design Manual, Oklahoma State University, Oklahoma, 1982.
8. D.A. Ball, et. al., "State of Art Survey of Existing Knowledge for the Design of Ground Source Heat Pumps", Report to Union Carbide Corporation, Battelle, Columbus, Ohio, 1982.
9. L.A. Salomone, "Thermal Behaviour of Fine Grained Soils", National Bureau of Standards, Building Science Series, BSS 149, 1982.

FIGURE 1
SHIPMENTS OF UNITARY AIR-TO-AIR HEAT PUMPS
IN THE UNITED STATES (6)

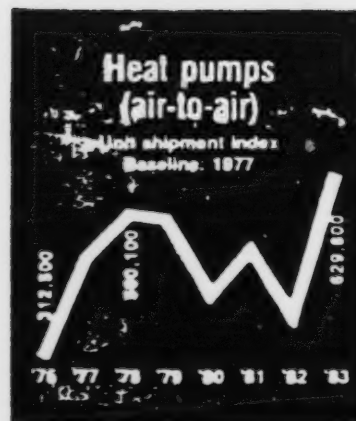
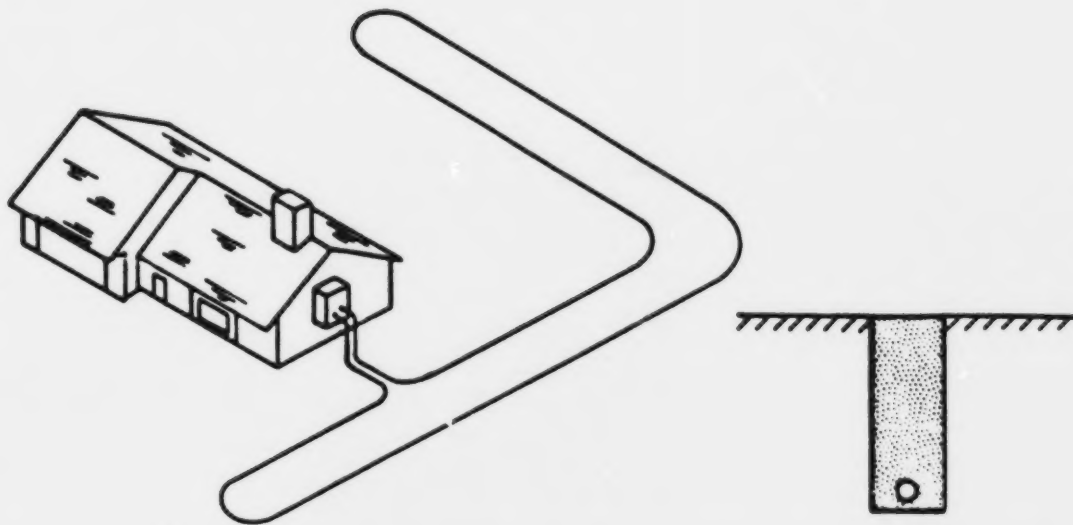
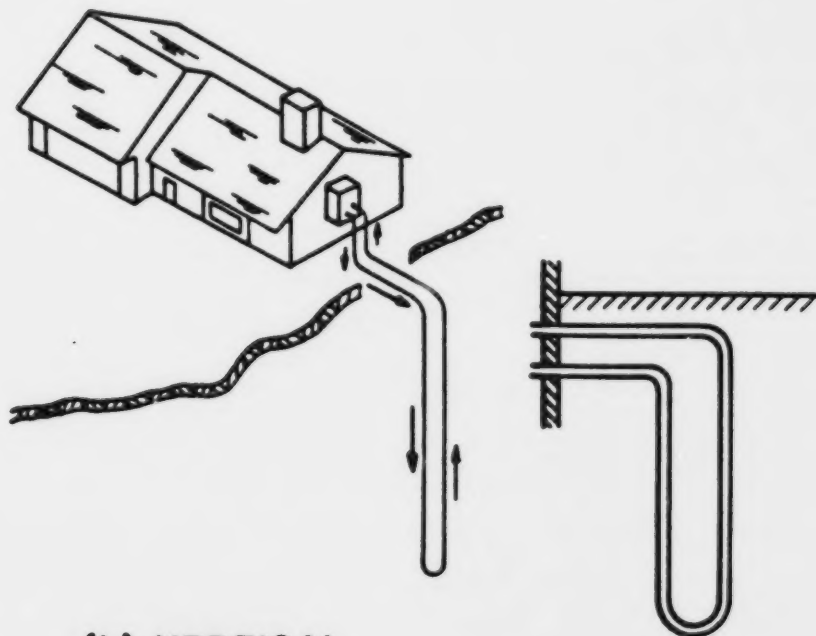


FIGURE 2
TYPES OF GROUND COUPLING SYSTEMS (7)



(a) HORIZONTAL



(b) VERTICAL

FIGURE 3
TEMPERATURE CHANGE OF FLUID IN A TYPICAL
GROUND COUPLED SYSTEM

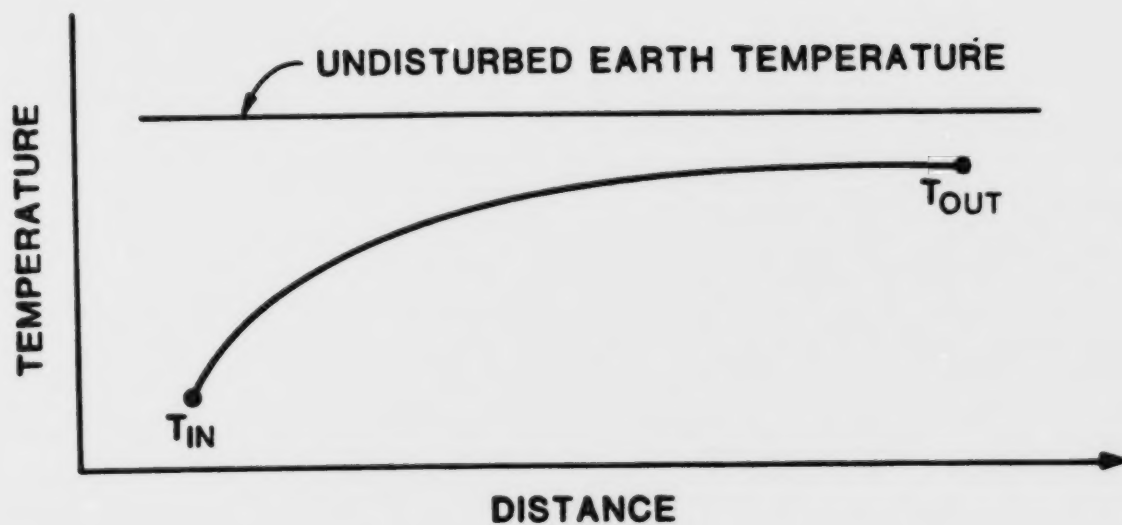
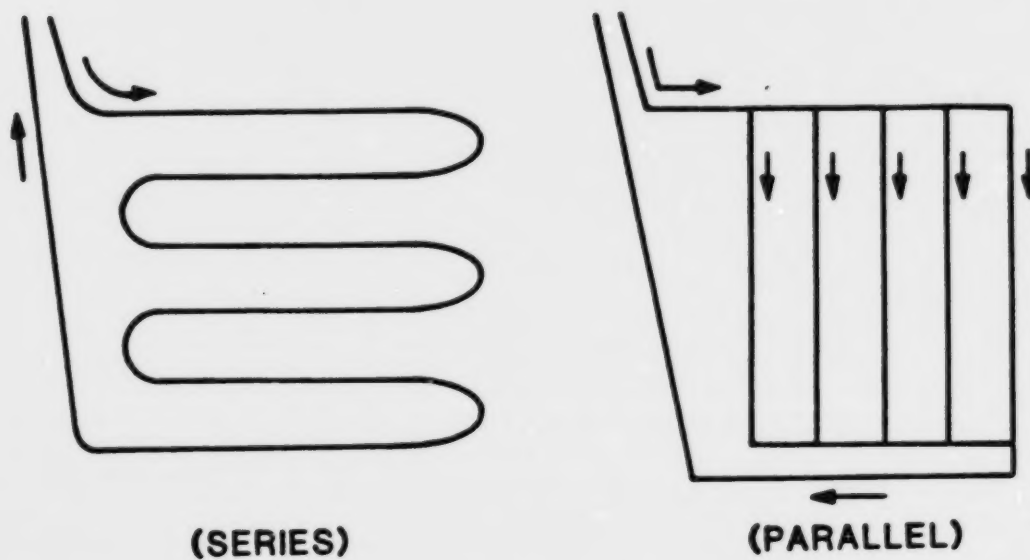
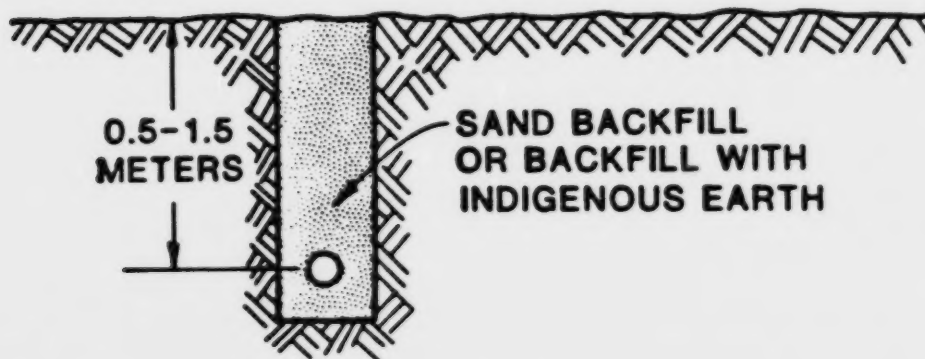


FIGURE 4

TYPES OF HORIZONTAL GROUND COUPLING SYSTEMS (8)

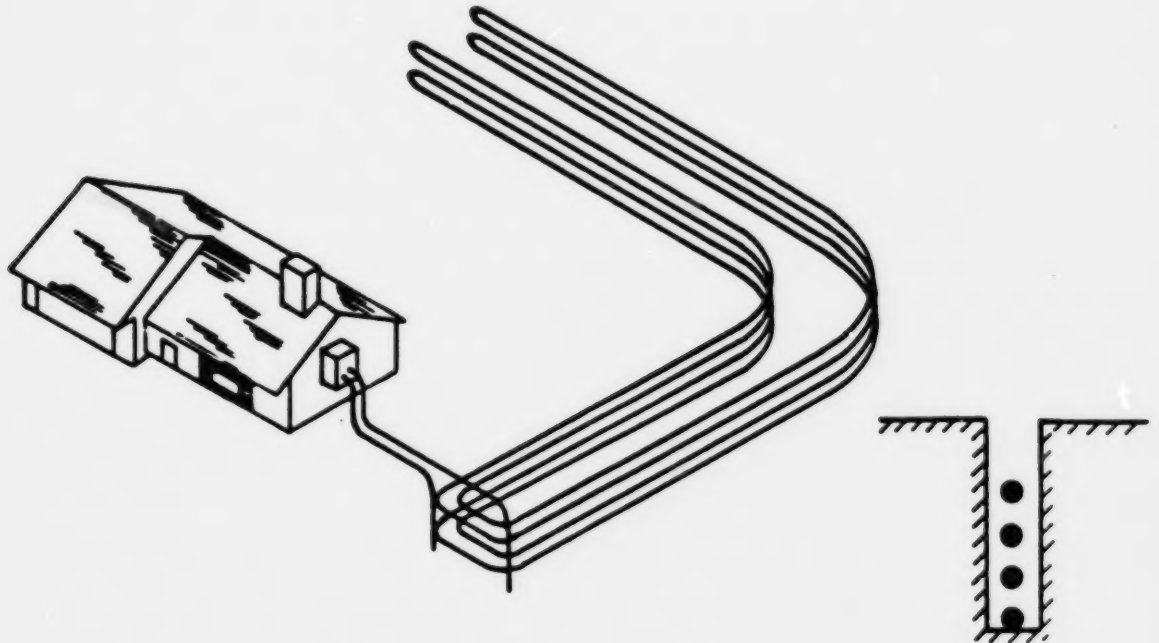


PLAN VIEW



CROSS-SECTION VIEW

FIGURE 5
A FOUR PIPE PARALLEL
HORIZONTAL GROUND COUPLED SYSTEM (7)



EARTH COIL TYPE: HORIZONTAL-FOUR PIPE

FLOW PATH: PARALLEL

**TYPICAL PIPE SIZE: PARALLEL PATHS 3/4 TO 1 INCHES
HEADERS 1 1/2 TO 2 INCHES**

**PARALLEL PIPE LENGTH: 500 FT. MAX. PIPE LENGTH
(3/4 INCH)**

**750 FT. MAX. PIPE LENGTH
(1 INCH)**

BURIAL DEPTH: 7 FEET, 12 INCH SPACING

FIGURE 6
TEMPERATURE VARIATION
WITH DEPTH FOR THREE SOIL TYPES (7)

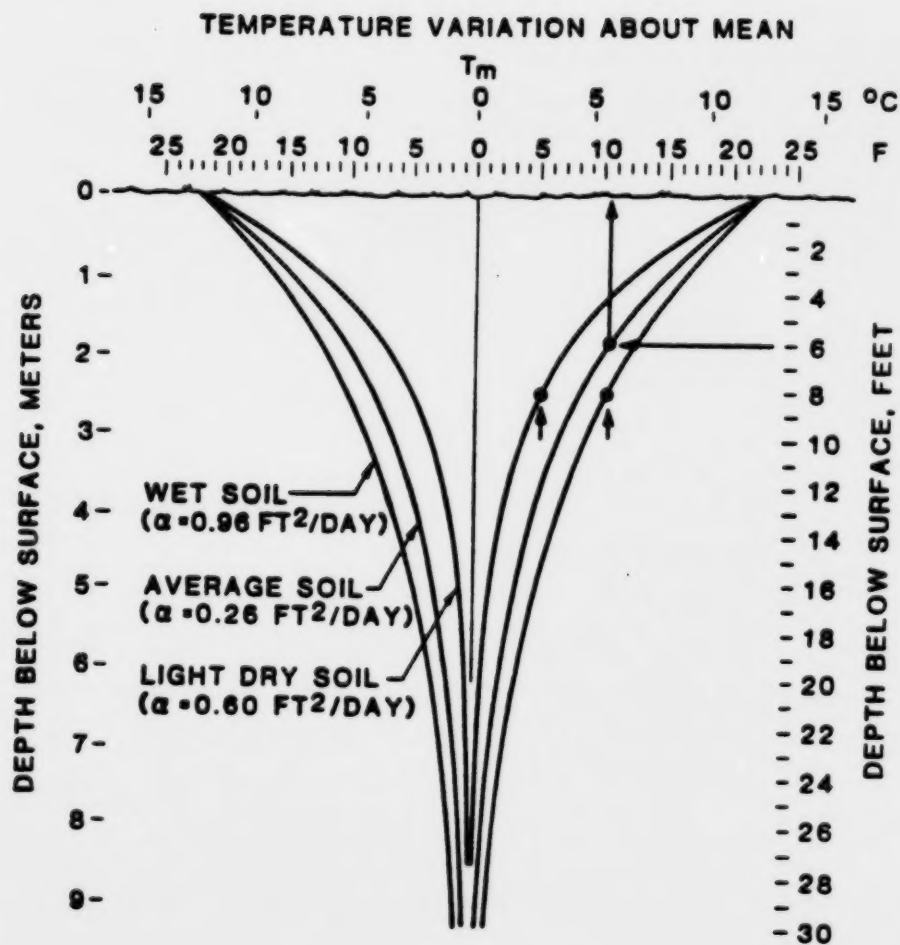


FIGURE 7
SEASONAL TEMPERATURE VARIATION
AT VARIOUS DEPTHS (7)

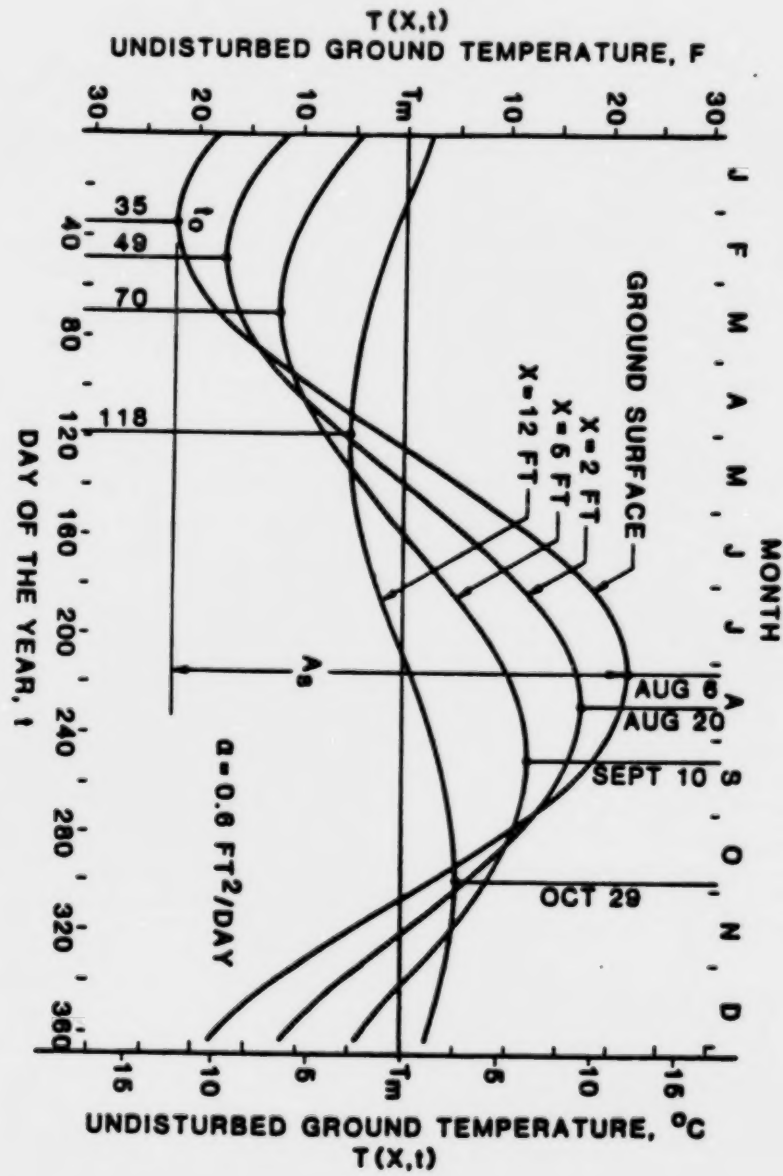
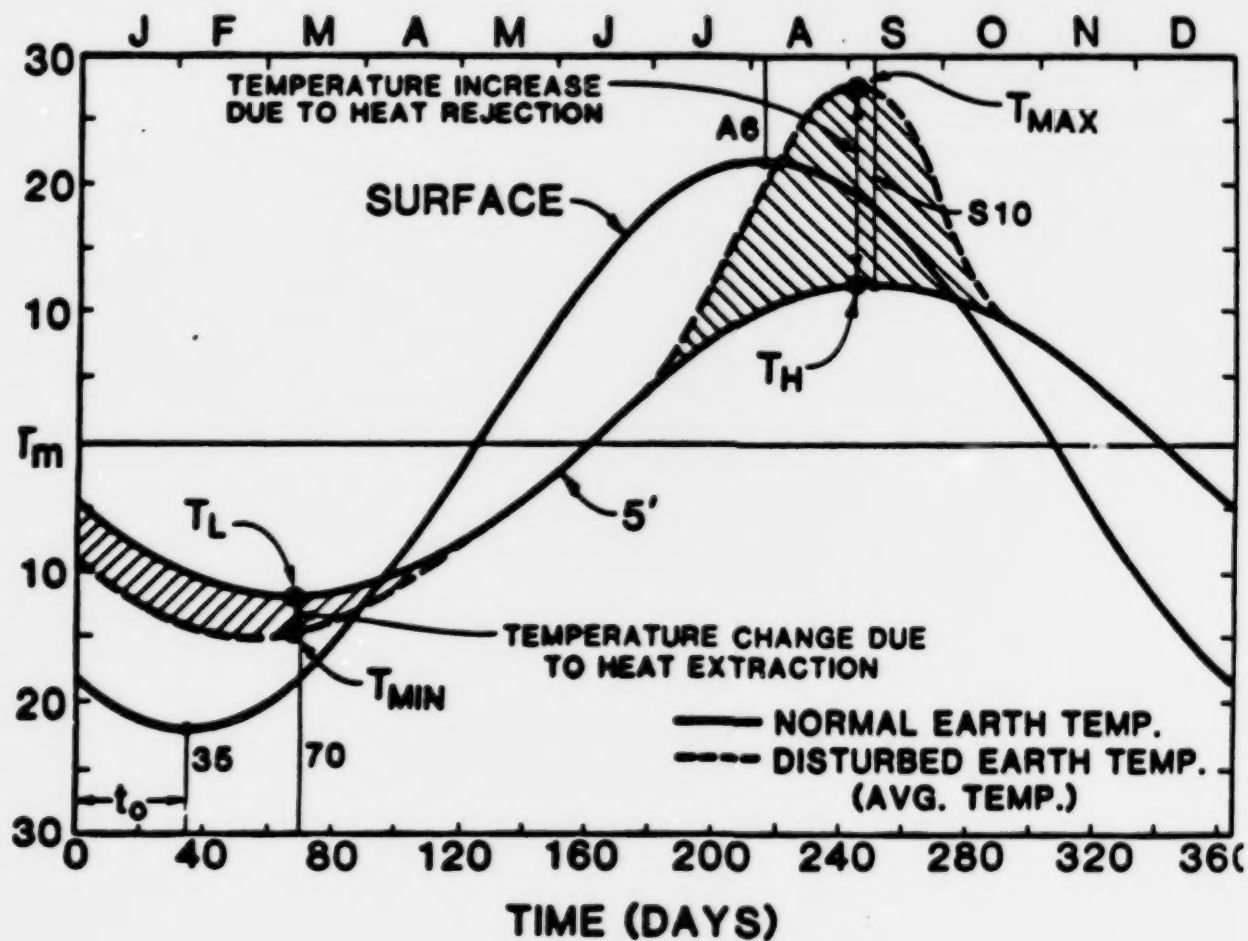


FIGURE 8
THE EFFECT OF A HORIZONTAL GROUND EXCHANGE
ON THE LOCAL SOIL TEMPERATURE (7)



ANNUAL SWING A_8 ($^{\circ}F$)

FIGURE 9

A TYPICAL ANNULAR VERTICAL INSTALLATION (7)

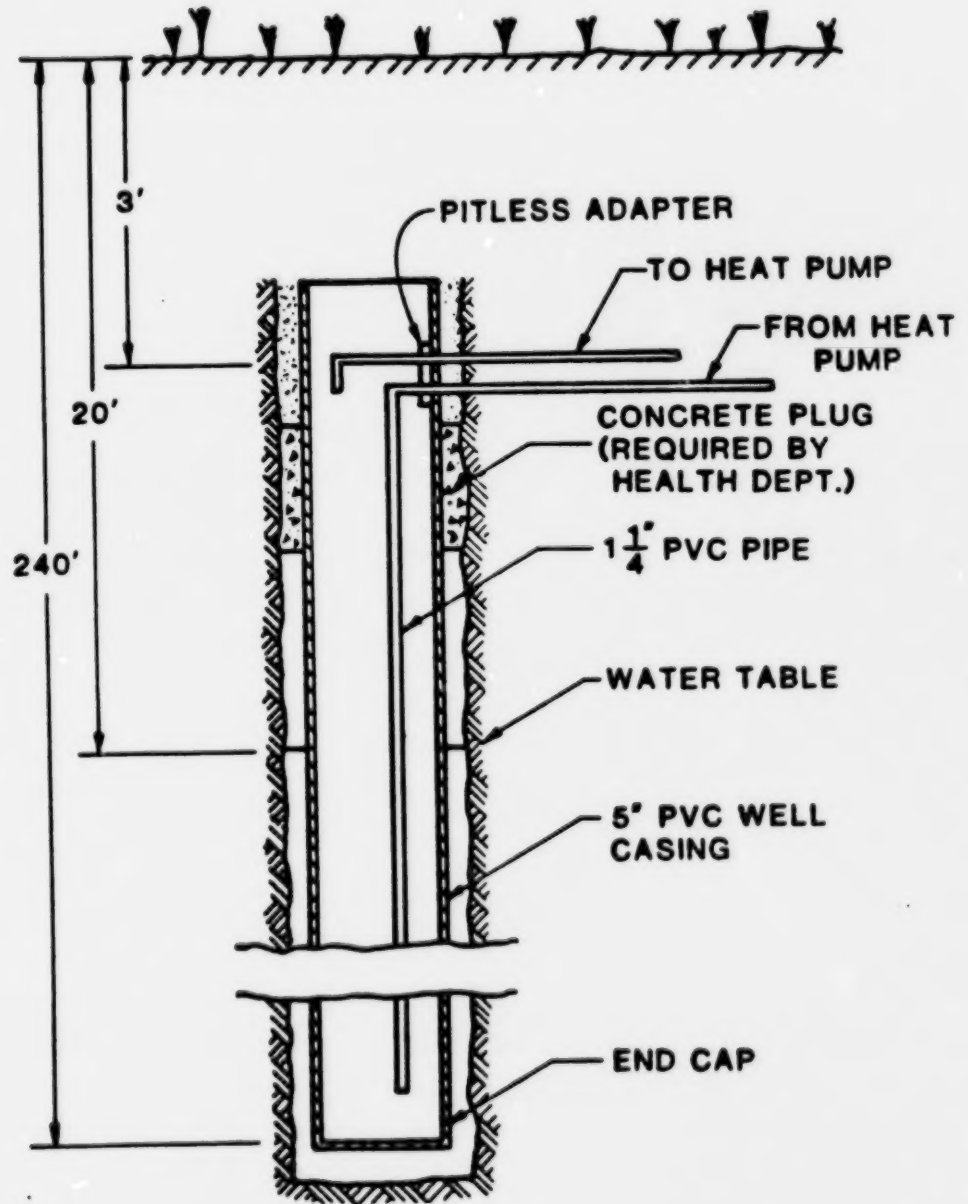
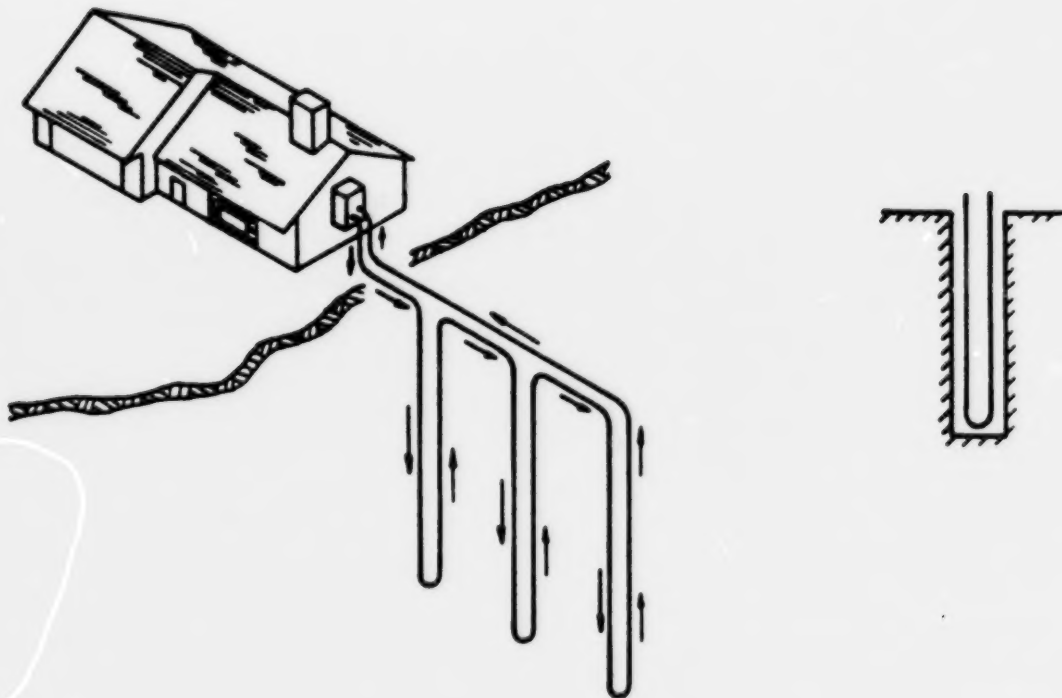


FIGURE 10

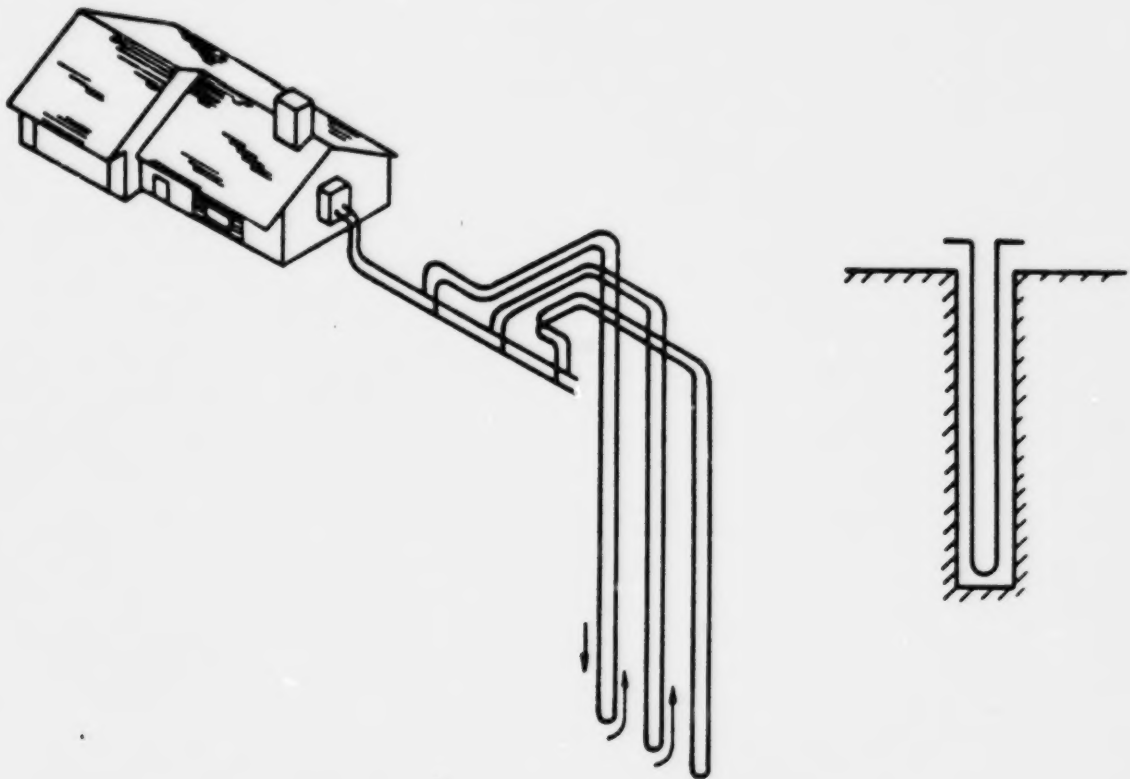
A TYPICAL SERIES VERTICAL GROUND INSTALLATION (7)



EARTH COIL TYPE: VERTICAL-HAIRPIN (U-BEND)
FLOW PATH: SERIES
PIPE SIZES: 3/4, 1, 1 1/4, & 2 INCH
BORE LENGTH: 100 TO 175 FEET/TON
PIPE LENGTH: 200 TO 350 FEET/TON

FIGURE 11

A TYPICAL PARALLEL VERTICAL GROUND INSTALLATION (7)



EARTH COIL TYPE: VERTICAL-HAIRPIN (U-BEND)
FLOW PATH: PARALLEL
PIPE SIZES: 3/4 & 1 INCHES
BORE LENGTHS: 100 TO 200 FEET/TON
PIPE LENGTHS: 200 TO 400 FEET/TON

FIGURE 12

THE OPTIMUM SIZING OF A GROUND COUPLED SYSTEM

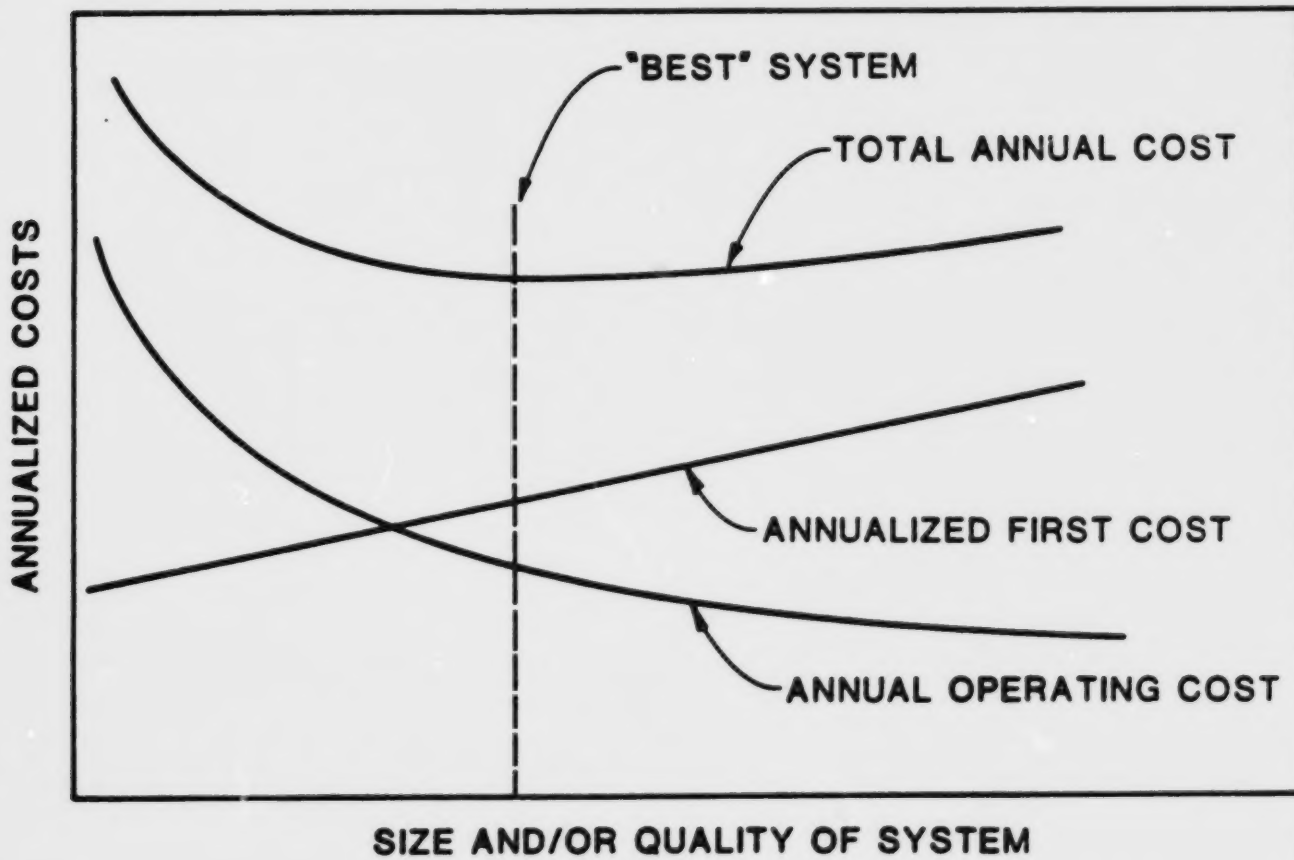


FIGURE 13

VERTICAL EXCHANGERS TESTED AT OKLAHOMA

PARALLEL EARTH COUPLING DESIGNS WITH THERMOCOUPLE LOCATIONS

- NOTES: 1. •-DENOTES THERMOCOUPLE LOCATIONS
2. ALL EARTH COUPLINGS 100 FT. IN LENGTH
3. P.E. - POLYETHYLENE, P.B. - POLYBUTALENE

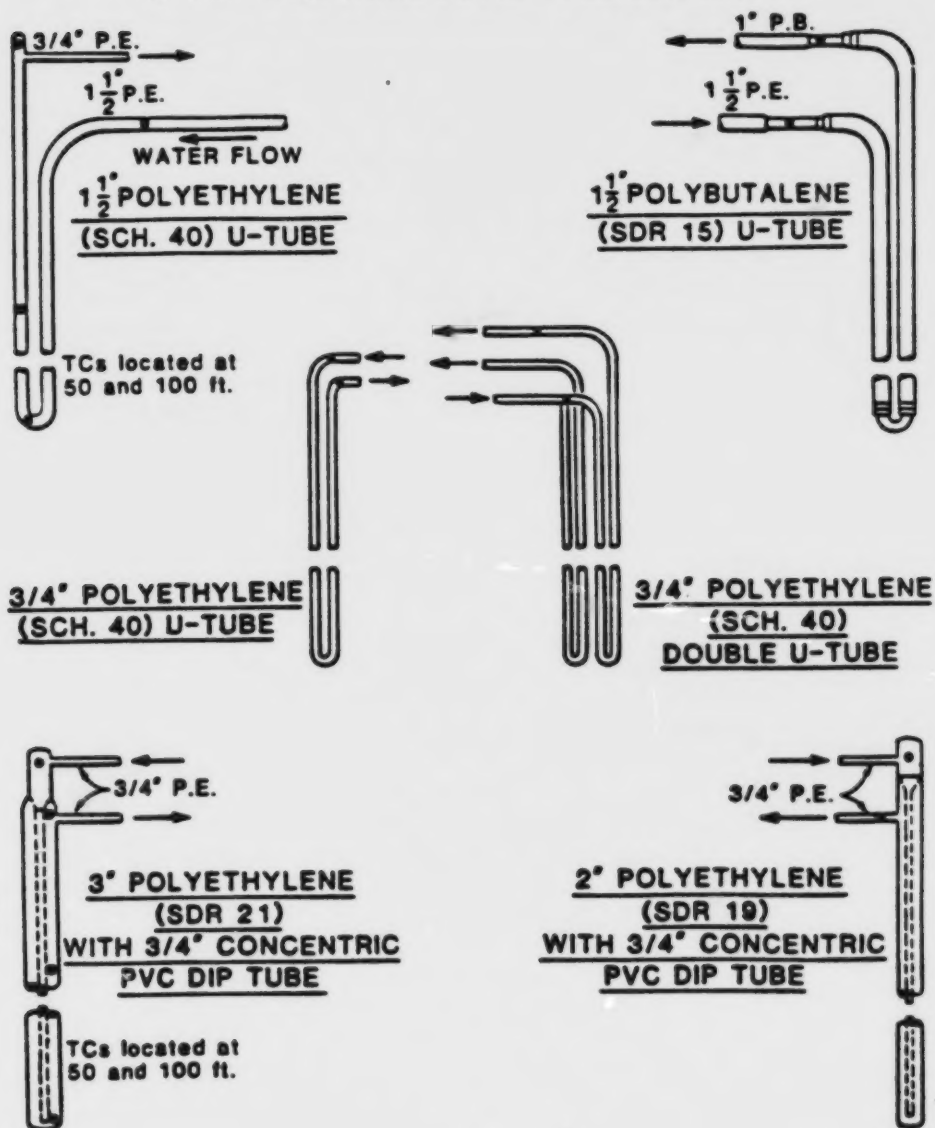


FIGURE 14

THE LOGIC FOR SIMULATION OF A GROUND COUPLED SYSTEM

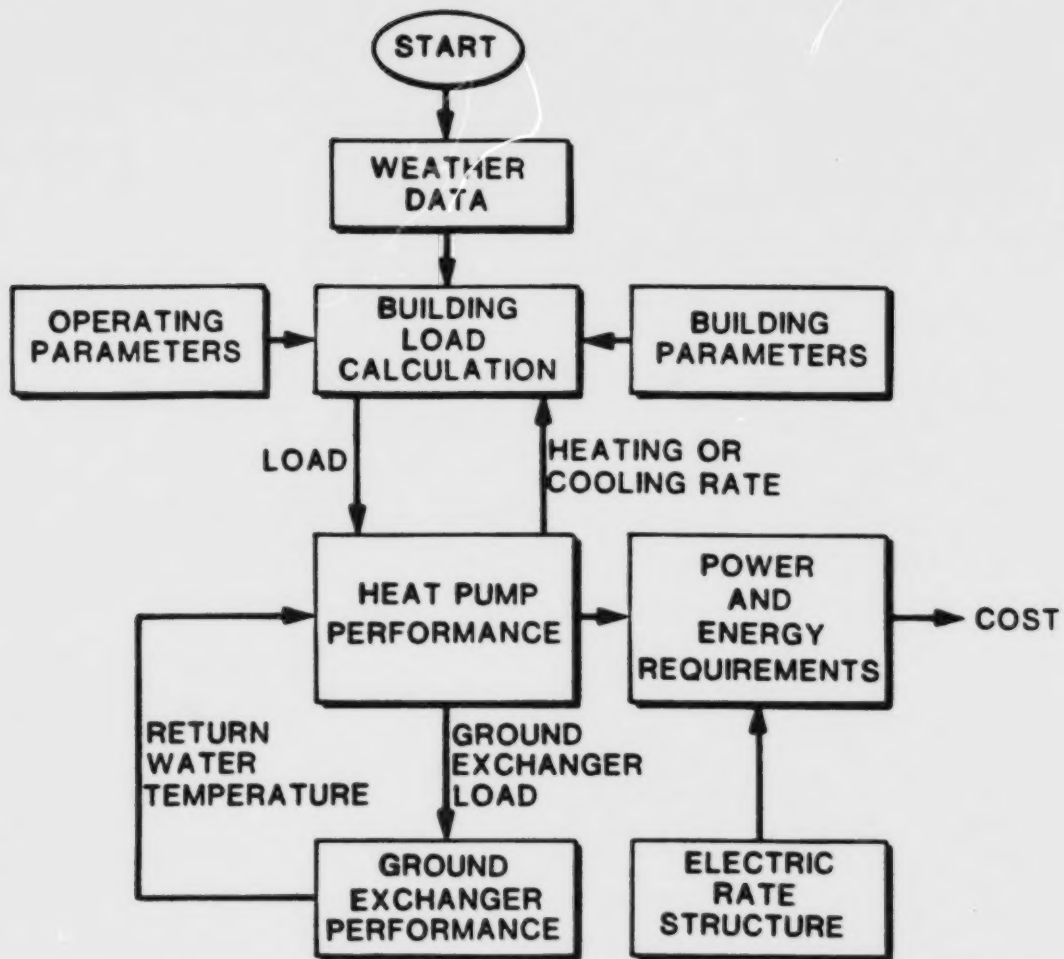
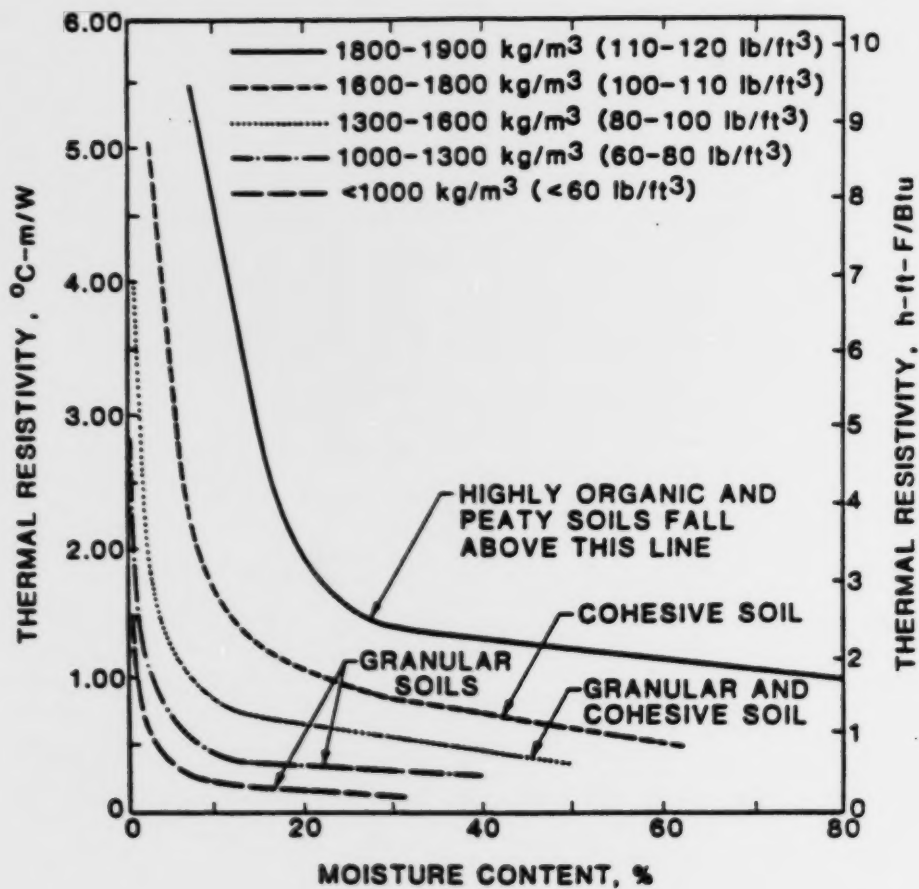


FIGURE 15

SOIL RESISTIVITY AS A FUNCTION OF MOISTURE (9)



SPEAKING NOTES FOR
SVEN G. OSKARSSON
SWEDISH ASSOCIATION OF HEAT PUMP MANUFACTURERS
PRESIDENT CANTHERM HEATING LIMITED
ST. LAURENT, QUEBEC

APPLICATIONS
IN
SWEDEN

AIRPORT HOLIDAY INN
970 DIXON ROAD
FIESTA BALLROOM

JANUARY 10, 1985
8:30 A.M.

S.G. Oskarsson

Sven Oskarsson is President of Cantherm Heating Ltd. He attended the technical institute of Kaarlstad, and has a M.B.A. and B.A. from the University of Gothenburg. His business experience including work in Volvo, in manufacturing and planning and later in the engineering and design departments of Thermia, has contributed to his current interests in heat pumps.

During the day we will hear about many interesting applications in North America. Most of the expertise I know on this side of the Atlantic, is participating today, so I will concentrate on ground source heat pump applications in Europe and, in particular Sweden, because that is where the ground source heat pump has taken off the fastest.

The climate in mid-Sweden is somewhat colder than Toronto in the winter (around 8,000 degree days), and no air conditioning is used at all in the summer.

The relative pricing of oil and electricity is comparable. In most places in North America, as in Ontario, the gas prices are competitive. Natural gas is not available in Sweden. Here there is the necessity of air conditioning, which is an additional demand that ground source heat pumps can supply and part of the necessary investment in most of the buildings and applications that we are going to discuss later.

So, I would state from the very beginning that what has taken place in Sweden, should without a doubt take place in North America, tenfold.

Let's look at what this workshop is about.

The Ground Source Heat Pump

In my talk, I will not discuss the heat pump as such. Heat pumps are known. I just want to state, with as much sincerity as possible, that you can't take any of the normal water based heat pumps on the North American market and use them for ground source heat pumps in our climate, it is just not possible. The design conditions are different.

I guess in Sweden, a workshop like this would be called, heat pumps systems with Anergy sources. Anergy being the energy under the temperature demand. With this definition, we come to the conclusion that a heat pump can utilize different energy sources that are renewable and always available. To understand the explosion of heat pump installations in Sweden, we have to approach our problem from the energy source.

The Swedish Minister of Energy is coming to Toronto, February 5th, and we are going to have a seminar about heat pumps. The Swedish Export Council is inviting Canadian business to this seminar. The Minister says, if we look at heat pumps from a historical perspective, "the breakthrough is one of the most important technological events during the 1980's."

The Heat Pump in Sweden Today, An Explosive Development

In 1978, the energy commission said in their strategical plan: "heat pumps will have an extremely marginal impact on the energy supply/demand pattern during the 1980's." More than 50,000 heat pumps were sold in Sweden to 1983 and it is the residential heat pumps that have increased in number. Of the more than 50,000 in operation, only 10,000 are heat pumps with air as an energy source. Roughly 80 per cent of the 40,000 are ground source heat pumps.

Today, the same energy commission says: "there can be as many as 150-250,000 heat pumps in Sweden by the year 1990." (That is on a population of 8 million.)

The situation can be compared to Ontario, although, we have a more expressed need for heat pump technique in Ontario than in Sweden.

This explosion of heat pump installations has not been without problems. It was a fairly lucrative market in the beginning and the knowledge among the manufacturer/installer has been too limited with bad performance as a result. That is why there has been a tremendous effort and co-ordination from the Government to get a heat pump installers' development program together.

The partners are the Swedish State Hydro Board, the Swedish Government and all heat pump manufacturers and the Installers Association. You have to remember, that there is no natural residential sector of refrigeration mechanics in most countries in Europe, as air conditioning is not necessary. So the challenge to develop this whole new trade was tremendous and was started in 1978-79.

Enormous Possibilities

Heat sources for heat pumps exist all over. To use air, ground, lakes, sewer systems and ground water, we could easily get 50,000 TWH of energy yearly in Ontario and I believe that is more than half of the oil presently used.

Terratherm (or horizontal loops in the overburden)

Today, this system is the most common in Sweden. There are approximately 32,000 of these installations, mostly in small houses. They are saving approximately 350-400 million kWh/year (40,000 cubic meters of oil). A terratherm system for a typical home needs a ground surface of roughly polyethylene and is normally buried one meter deep, with a spacing of less than two meters. The energy in the ground is then circulated to the heat pump with an anti-freeze solution.

The maximum power extraction per meter of pipe varies between 10-30 watts (factor of 3). That depends on the soil and water content.

In addition to the smaller residential buildings, there are today several large horizontal loop projects for apartment buildings. There is one with 168 apartments installed in the beginning of 1950, that has a combination of horizontal loops and waste water from the sewer system.

The world champion for horizontal loops is at a place called the "Big Field" and it really deserves that name. In the field there are 30,000 meters of pipe and all these pipes feed to a heat pump that heats 160 apartments. They have had some problems with the heat pump, they had to change oil filters and initially they also complained about low temperatures on the domestic hot water, but there has never been any problems using the ground as the source.

Systems bigger than this have to go vertical, mostly for surface demand.

In Sweden, as in Ontario, there is a tremendous potential for use of ground water.

A tenth of all apartments could be heated with ground water (Sweden). Presently, we have installed 4,000 so-called energy wells, that is, using ground water indirectly. (We are going to look a little closer at that later.)

The ground water temperature at 10 meters deep is mostly 4.5°C, so we will normally find better conditions in Ontario.

There are approximately 40 big installations using only ground water. The energy wells, which I said were 4,000 are increasing by 2,500 and 3,000 yearly. By bigger installations, I mean installations that have an output of greater than 200 kW.

Direct Use of Ground Water

When we normally talk about ground water, one uses the ground water directly to the heat pump, that means that the ground water is introduced to the evaporator. This is called an open system.

Vertical systems are when one takes vertical closed loops and picks up heat from the surrounding soil around water and/or rock. This closed loop system will contain an anti-freeze solution. The borderline between what is called vertical loop and ground water is not clear cut. There are cases where at the beginning ground water was to be used but vertical loops became the solution.

A typical installation is a senior citizen home, of ten row houses outside Stockholm. The new system reduced their oil consumption from 21 to 3 cubic meters of oil. This installation was fairly expensive, as the row houses had direct resistance electrical elements from the beginning.

Another project originally designed for direct electric baseboard, the Swedish State Hydro Board succeeded in getting the community interested in using a heat pump instead and the heat source became ground water. In this case, they had specified a system with closed vertical loops, but as the ground water supply was high, they turned around and used the ground water.

The wells were drilled in advance, the foundation was built on top and by this a lot of unnecessary connections and manifolds were avoided. There is 10°C ground water coming up. Later it was necessary to install a heat exchanger between the ground water and the heat pump, to avoid the evaporator being exposed to the aggressive water. This installation is close to the Baltic Sea and there was saline water coming in. From this heat exchanger, the heat is injected to the heat pump through a closed loop system with water and glycol. In this case the system is integrated to use the exhaust air from the buildings, as each building has mechanical ventilation. The system is designed for a 53°C feedline temperature to radiators and domestic hot water is produced by superheat (design temperature +70°C).

The installation has two heat pumps, each of them 25 kW. The C.O.P. under monitored conditions is 3.

The heat pump is designed to take care of 80 per cent of the peak load. The auxiliary heating is taken care of by the oil oil boiler.

Lake Heat

Tremendous amounts of heat can be tapped from our lakes and water courses. Sweden having 52,000 reasonably large lakes would be able to filtrate 600 TWH. In Ontario, with Lake Ontario, Lake Erie, Georgian Bay, etc., we are above that. The question is, how much of this is realistic to use. Perhaps 5 per cent, in which case 15-30 TWH per year is the equivalent of 5-6 nuclear power plants.

Strangely with lakes it makes more sense to use those in the north.

Most people believe that a temperature of $+4^{\circ}\text{C}$ exists at the bottom of a lake, as the density is highest at $+4^{\circ}\text{C}$. Thus, they believe the water temperature at the bottom should be $+4^{\circ}\text{C}$ and stay constant all winter. However, this is not so and the major reason is the wind, and its direction. The largest impact on temperature stratification in a lake occurs when ice formation takes place. The longer the lake is ice free, the colder the water will be at the bottom when it is turned over during the fall period. For this reason lake heat is more interesting in the Northern part of North America and more specifically Northern Ontario.

Rivers and seas are more difficult to assess as the water currents have a large impact. The temperatures in rivers will often go only to some hundredth of a degree above 0.05°C . In coastal waters, the cold water will be pushed down into very deep sectors, but we have also found on the west coast of Sweden extremely warm caves in the bottom, where water from the Gulf Stream is trapped.

Heat pumps using lakes as an energy source are today installed in large numbers and their heat output is from 1 MW to 20/30 MW, and they are normally used as base load on the district heating plants.

The one outside Stockholm which is 50 MW, saves 8,000 cubic meters of oil per year. Two more installations are just now under construction. These are open systems where the lake water is pumped directly into the evaporator. After that the return water ($+2^{\circ}\text{C}$) is pumped back a fair distance from the intake.

The other main system is the so-called closed loop system (the terratherm system). These have to be anchored to the bottom of the lake. Inside those pipes we have an anti-freeze solution, normally a glycol mix, that is extracting heat from the water and gives it to the evaporator. Here, one can operate with much lower temperatures than in the open system. Through deliberate ice formation on the pipe, one can use latent heat and the thermal conductivity increases. Possible heat extraction is 20-40 water per meter of pipe.

One example of using a river is the Kunsonu (Customs Station) 60 km north of the Arctic Circle. The heat pump gives all the heat to the station. The river has ice six months a year, its temperature is approximately 0.05°C in the winter.

A third system used is through a so-called open system - really making ice. This technique gives tremendous saving potentials in all our water courses. It puts a very big demand on the evaporator as well as the mechanical transportation of all the ice that is formed.

Some Examples

In one situation, 140 typical Swedish homes were all heated with oil, but nowadays are heated with a heat pump that takes the heat out of a lake.

During the first year of operation, they cut their energy costs in half and in the second year by 60 per cent. The condenser of the heat pump is connected directly to the district heating return line. The temperature will be increased with 10°C. The outgoing feedline temperature will then be about 60°C. A culvert system injects the hot water from the plant to sub-plants in every home. There is a heat exchanger in each home that exchanges the heat from the district heating water to radiator water and domestic hot water. The heat loss of the whole development is 1.5 MW. The heat pump is 750 kW (+2.5°C). Add-on heat is with the old oil boiler. During the first year of operation 1981-82, the heat pump took care of 3,360 MWH, which was 85 per cent of all energy and saved 400 cubic meters of oil. It saved roughly 50 per cent of earlier oil consumption.

Ice Heat

The technology with ice machines is 50 years old, but taking care of heat created when producing ice has not been looked upon as feasible. With the help of ice machines the energy can be extracted in our rivers, and water courses down to the freezing point. The energy potential is enormous as big cities are normally near rivers or lakes.

The so-called ice heat pump or the ice machine is not yet regarded as being fully developed, but considerable research is going on. One covers 35 apartments in five small buildings. That installation has 120 kW.

With these heat pumps we can take care of a tremendous amount of heat that exists in our rivers, but it is important when it comes to the use that the water current is good enough and has an even flow, so the ice transportation can take place, says Bengt Lindquist, who is the project manager from the Building Research Council.

Technically, the ice handling and the mechanical cleaning of the evaporators must be improved before the system can be looked upon as commercially viable.

The Swedish Hydro Board has a 1980 installation that has a heat output of 100 kW. The river temperature in the winter is 0.05°C. All the heat released through the ice formation is used to heat the Swedish State Hydro Board laboratories. They are producing 30 tons of ice every 24 hours during the winter and using a radiator system that is designed for 40°C.

Even though this installation has had many thousand running hours per year it has some problems. One problem is the defrosting of the plate heat exchangers. This is done by using hot condensate, directed to the evaporator plates, causing a defrosting and the ice falls off into the ice crusher. Further development of this process is necessary to achieve reliable operation.

We also have some practical problems with ice crushing.

Before the ice is pumped into the river, it has to be crushed into small pieces and then mixed with water to an ice mixture. It is a problem when it gets stuck in the pipes many times.

Waste Heat

Among waste heat sources, the heat used from sewer systems is the most intriguing. This heat source, is the cleaned sewage water that goes through the heat pump, with a temperature drop of 5-10°C. In another installation in Sweden, one is using the untreated water; this demands evaporator cleaning within a very short interval.

Filtration plant people are very often against this type of system as the temperature decrease of the water makes the biological purification process diminish. Waste heat as a heat source is relatively easy to handle. It is very seldom that a temperature sink drops below 8-10°C even in the winter. One problem can be that there are large variations in the water flow over different hours of the day. There are several heat pump systems in Sweden that are using sewer systems as a heat source, mostly to deliver heat to a district heating plant.

It is also possible to combine different energy sources and in one of the major cities of Sweden, they are using both the sewer systems and the lake water. In this case, from the Baltic Sea to introduce 10 MW into the district heating network.

The largest operation, up to now, is in Uppsala. It has a load of 40 MW and that gives heat from more than 20,000 homes which is roughly 14 per cent of Uppsala's total heat demand.

A lot of communities are now in the process of investing in sewer system heat pumps.

For instance, in Gothenburg, there is one installation of 27 MW and one to be built of 135 MW.

The Swedish District Heating Association has today approximately 96 heat pumps ranging in size from 1-50 MW and they were successfully put into operation in 47 different district heating networks during the 1980's. Together these give the combined load of 900 MW. Sewer systems as a heat source are well ahead when it comes to heat pumps.

Large Heat Pumps

The largest heat pump in the world, is a gigantic heat pump installation outside Stockholm, that will use the waste heat from the city.

This plant will have a load of 150 MW. Originally this was to be a coal plant, but the plans to supply heat to Stockholm's district heating network changed and instead it became the largest heat pump in the world.

The first step is planned to be ready during the fall of 1986 and it will be 75 MW.

In stage two, there will be an additional 75 MW and the two together will be 150 MW and should be started up during the fall of 1988.

The production cost for the first year of operation will be 4 cents per kWh and will go down to 2-1/2 cents in 1990.

The large scale heat pump technique has developed tremendously during the last few years.

Ambient Air

Outside outdoor ambient air theoretically ought to be an endless heat source, but different technical limitations for using it have been found by the Building Research Council who found the potential to be 50 per cent of what has been assumed to be a practical potential for lakes as an energy source.

Today, there are roughly 8,000 residential heat pumps installed with air as an energy source.

Air as an energy source is also used in some larger installations. We have one which is 2.6 MW output and also one in Gothenburg with 3 MW output. There is another with 1 MW under construction in the same community.

The largest heat pump with ambient air as a heat source is built outside Stockholm and this is 4.5 MW.

This heat pump is presently under construction in an area with 3,000 apartments and 6,000 working stations that are to be heated.

Exhaust Air As An Energy Source

Exhaust air from our buildings contains a tremendous amount of energy. The 20°C temperature on the exhaust air could give as much as 5 TWH of heat per year here in Ontario and as much in Sweden. That is roughly the same amount of energy as one

nuclear power reactor is producing. But exhaust air is a very hot and very debated energy source in Sweden, as it is decreasing the baseload for the district heating network. So the Government has made rules that exhaust air heat pumps are not possible to install, where district heating networks are in place. This is an amazing, but typically Swedish approach.

There are many installations now where the exhaust air is used as a source to produce domestic hot water.

These systems normally have a C.O.P. of 3.2 to 3.6.

This was a lot about applications with different energy sources, perhaps a little different than the ground source heat pump workshop indicates, but I think it is important to understand that the technology that we are discussing today is a technology with tremendous flexibility and the opportunities are there to combine and get the systems to run as close to 8,765 hours per year as possible.

Out of all the different installations, we have understood from the description here that there is a dramatic development of the ground source heat pumps and also larger numbers of horizontal loops compared to the vertical loops in Sweden.

SPEAKING NOTES FOR
F.C. HOOPER, PRESIDENT
HOOPER AND ANGUS ASSOCIATES LIMITED
CONSULTING ENGINEERS
TORONTO

ENGINEERING
FOR
BEST PERFORMANCE

AIRPORT HOLIDAY INN
970 DIXON ROAD
FIESTA BALLROOM

JANUARY 10, 1985
8:30 A.M.

Professor F.C. Hooper

Frank Hooper is President of Hooper & Angus Associates, and is Professor of Mechanical Engineering at the University of Toronto. A pioneer in energy conservation designs, heat transfer and solar energy utilization, he serves on many professional committees, and has been awarded the silver jubilee medal, and engineering alumni medal of the University of Toronto. Many technical contributions include papers and work on district heating, thermal and solar systems, housing and thermal energy storage.

Ladies and gentlemen:

I am particularly pleased to be able to participate in this workshop, and to note the high level of interest it has generated. The ground coil heat pump was one of my earliest enthusiasms, and it continues to be so.

In 1948, I undertook, on behalf of the University of Toronto, the design, installation and monitoring of a 3 horsepower ground coil heat pump installation in a residence in Port Credit, Ontario, not far from the site of this meeting. We were sponsored by Ontario Hydro, and I worked with a Hydro engineer, Bruce MacDonald, on the project. It was, I believe, the first or second ground coil heat pump installation in Ontario, and perhaps in Canada.

It served a 5-room bungalow, and over three years of operation gave a very satisfactory performance. The operation was closely monitored, including the ground temperatures which were recorded at several cross-sections about the coils by thermocouple arrays. Some of the output data are shown in Figures 1, 2 and 3.

The installation was fitted with three, 300-foot long, copper coils of 3/4 inch diameter, laid in trenches five feet deep on six foot centres, as shown in Figure 4, but only coils 1 and 2, totalling 612 feet, were used in the first test year. An ethyl alcohol antifreeze mixture was circulated in the coil. The compressor was a double twin, Freon 12, belt-driven unit with a 3 horsepower, 25-cycle motor. Three 2 kW auxiliary electric heaters were supplied. The seasonal average Coefficient of Performance (COP) for the heat pump was 2.47, and the rate of heat pick-up by the ground coil was 21.9 BTU/hr. lineal foot. These specifications and performance characteristics are very close to those associated with heat pumps being installed today.

The interesting thing about that installation from our point of view today, 35 years later, is that the reasons for installing the unit were essentially the same as those which motivate us today. There was a shortage of electrical energy in Ontario pending construction of thermal power stations, and nuclear power had not yet been shown to be a potential replacement for oil, which was recognized as being in ultimately limited quantity. Heat pumps were seen to offer very real energy and energy cost savings, but the air-to-air heat pumps, in our Ontario climate, have very low COP's and capacities in the coldest weather, just when the maximum demand occurs. This tends to bring the load on the public utility to about the same peak value as for resistance heating due to the dependence on auxiliary heaters, but provides a much lower seasonal load factor, an unattractive load for a public utility.

A ground coil heat pump avoids this unfavourable load characteristic, and promises a higher seasonal average COP. In a report I wrote for the Canadian Journal of Technology⁽¹⁾ in 1951, it was clearly demonstrated that these advantages could indeed be realized. It is, therefore, most instructive to inquire, at this time, why the ground source heat pump was not taken up immediately by the public, or at least that portion of the public which is technically well-informed.

The short-term answer in 1950 was that Ontario Hydro was experiencing one of its cyclic periods of short supply, and did nothing to encourage its use. Indeed, by talking about extra or penalty charges for electricity used for heat pumps, they sought to discourage such new loads at that time.

In the longer term, however, it was the total installed cost that discouraged their use, and we saw a considerable market develop for the significantly less efficient, but less expensive air-to-air heat pumps. The installed costs of the ground source heat pumps were relatively high because of two factors, heat source coil installation labour and equipment, and engineering design costs.

In air-to-air units these costs are small, because a single production design can be used in a wide variety of installations, and large production runs can reduce engineering costs on a per-unit basis to a very small amount. Indeed, it is economically necessary to undertake optimizing design studies for these units. These studies involve determining, from amongst the very large set of workable designs, the single optimum design. This represents the optimum balance between many design factors, such as the size and characteristics of the evaporator and condenser coils, the control system used, the motor characteristics, the fan sizes, the refrigerants and compressors used, and suitability for economic production. Investments of several hundred thousand dollars in such optimization studies can be justified, because perhaps 100,000 similar units will be sold, and the engineering costs associated with the optimized design will be only a few dollars per unit. Moreover, the installation of such units involves little individual engineering, so the overall engineering and installation costs are low.

In contrast, ground coil heat pumps must meet a broad range of installation conditions, usually requiring individual engineering assessment and design. The variables include differing soil thermal properties which vary with moisture

(1) Hooper, F.C.; "An Experimental Residential Heat Pump", Canadian Journal of Technology, 30: 180-197, 1952.

content and soil strata, differences in water table levels, in surface drainage, in available lot shape and size, and pump and piping requirements. Engineering costs, even for an installation to serve a modest 6-room house, can easily exceed \$1,000 if proper attention is given to the installation. Coil installation charges are additional and substantial, especially on limited or developed sites.

Of course, in these circumstances, specific engineering has often been by-passed in favour of rule-of-thumb methods of design. The result is, almost certainly, installations with less than optimum performance, frequently over-designed and with higher than necessary operating costs. In these circumstances they are less competitive than they might otherwise be with alternative heating systems.

The most direct challenge in the immediate future is to bring to bear the potential of modern compact computers and instrumentation, so as to carry out on-site evaluation and designs. In particular, my recent re-appraisal of the state of the various necessary technologies, suggests that a vertical bore-hole drilling rig could be equipped with thermal property sensors such as thermal conductivity probes and an on-board computer, which when supplied with the characteristics of the building heat load could determine when the drill hole had reached a depth sufficient to meet the heat source requirements. By this means, it may well be possible to bring the superior performance of the ground source heat pump into an economic position where it can win a large market share.

There is work to be done before a solid success can be expected. There is a need for some well-planned testing on vertical bore-hole thermal sources, integrating efficient methodologies of borehole drilling and coil installation with the corresponding design and analysis software. This might also offer sufficient background to permit the establishment of consumer standards, which more than anything else would raise consumer confidence in the ground source heat pump. We are fortunate in having already in the literature much of the basic soil thermal property work essential to such an undertaking, although moisture migration problems in response to temperature gradients are not yet well understood.

In brief, it appears that our technology may have advanced to the point which will permit competitive success in the market place for the ground source heat pump which has long been understood to have a superior performance in the Canadian climate.

HOOPER: HEAT PUMP

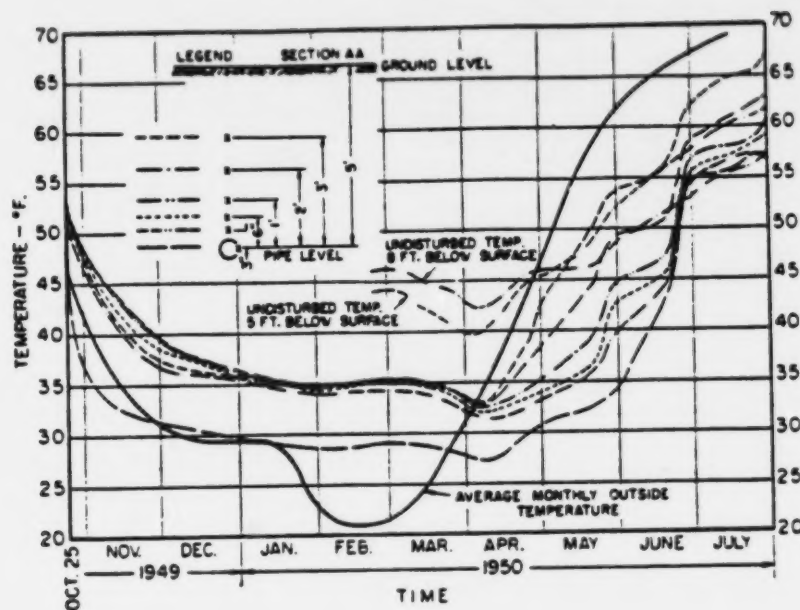


Fig. 1a. Ground temperatures at coil section A-A.

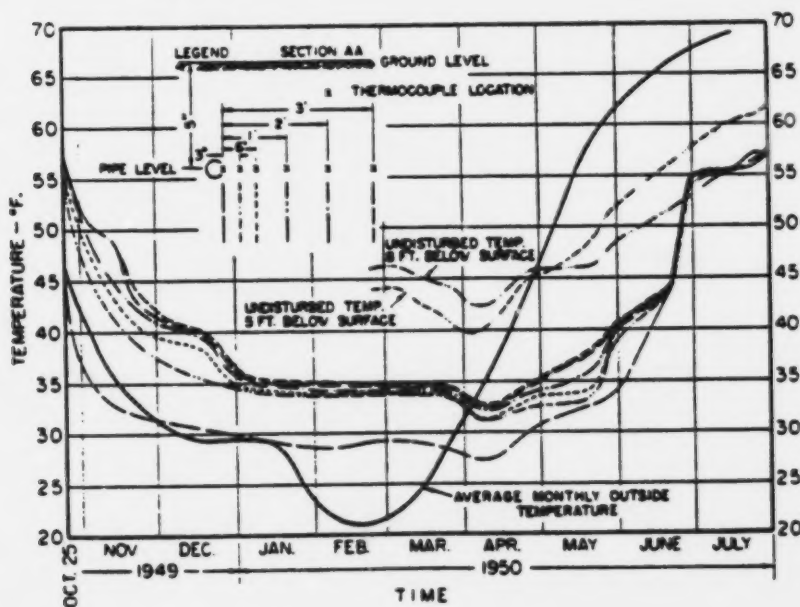


Fig. 1b. Ground temperatures at coil section A-A.

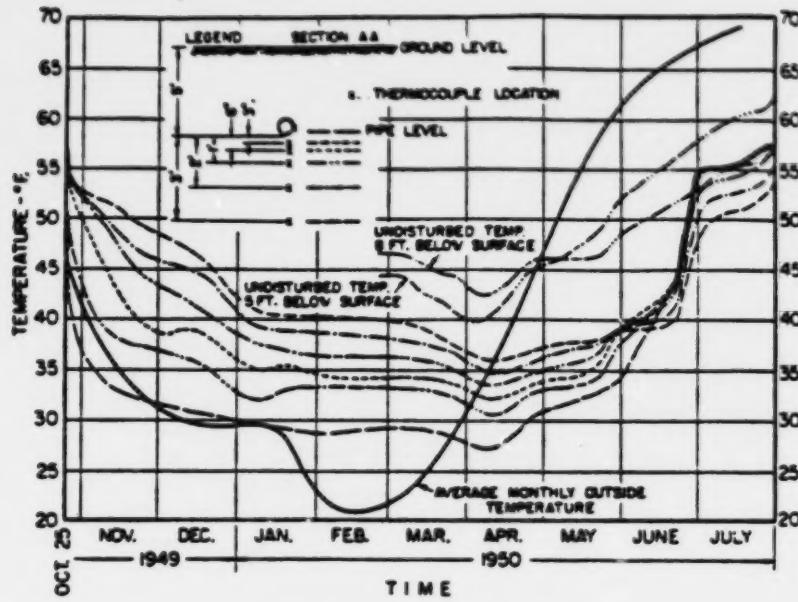


Fig. 1c. Ground temperatures at coil section A-A.

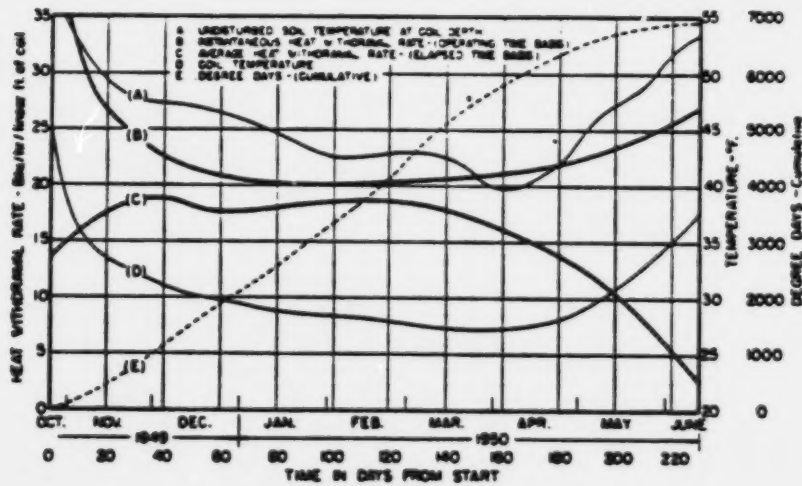


Fig. 2. Ground coil performance data.

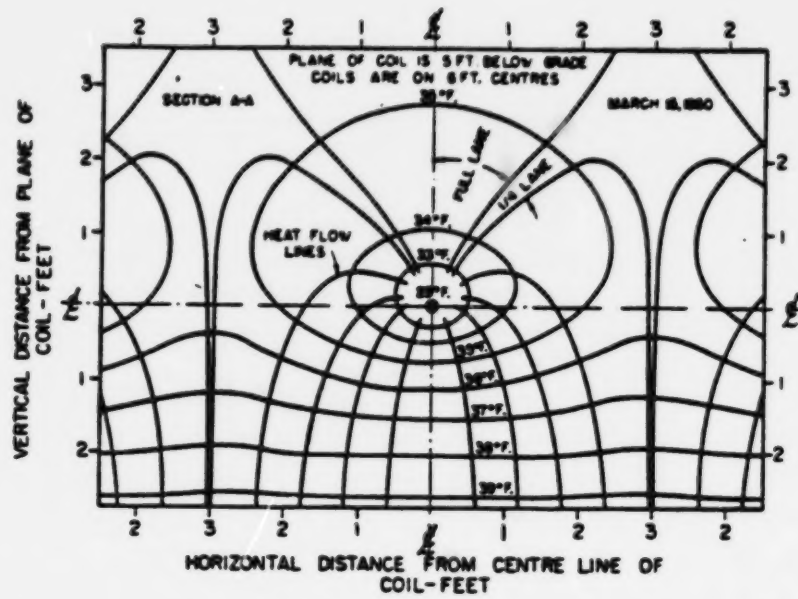


Fig. 3. Heat flow pattern around the ground coil.

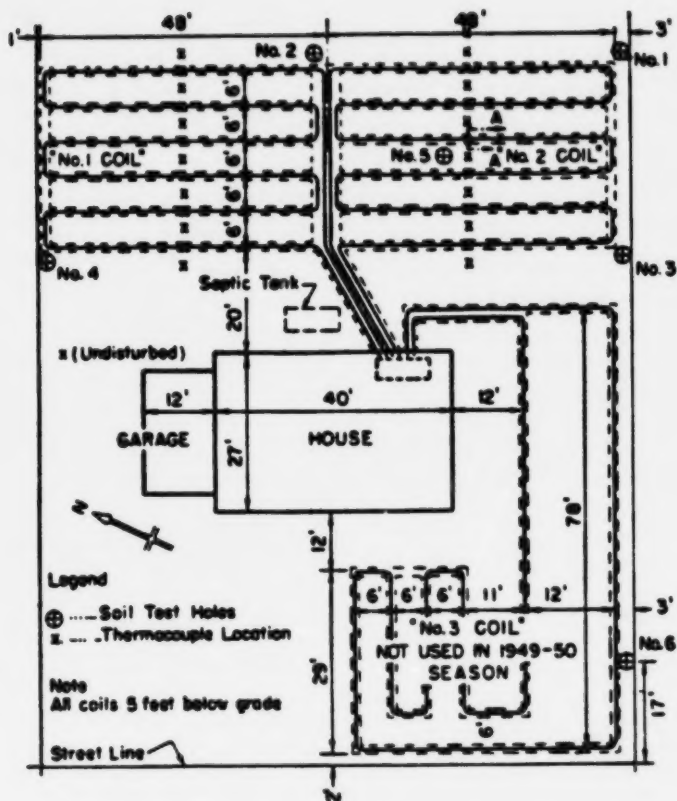


Fig. 4. Layout of ground coils.

SPEAKING NOTES FOR
SVEN G. OSKARSSON
SWEDISH ASSOCIATION OF HEAT PUMP MANUFACTURERS
PRESIDENT CANTHERM HEATING LIMITED
ST. LAURENT, QUEBEC

GROUND SOURCE HEAT PUMPS
- A REALITY IN CANADA -
SYSTEMS SUITED FOR URBAN USE

AIRPORT HOLIDAY INN
970 DIXON ROAD
FIESTA BALLROOM

JANUARY 10, 1985
10:20 A.M.

Since the beginning of time, man has been taking advantage of solar energy for his home comfort. However, it took the effects of soaring energy costs and by that an increasing interest in energy conservation to call attention to a 50 year old idea - the ground source heat pump - and to look anew at the possibilities of exploiting the enormous free-of-charge energy source of the sun.

Energy conservation implies efficiency, and the ground source heat pumps are the winners when they are compared to any alternative from meeting domestic or commercial energy management alternatives.

The effects of system efficiency are best demonstrated by direct operating cost comparisons with other alternatives. This graph is taken from Canadian Enerdata and clearly underlines both short and long term benefits of ground source heat pump systems. Furthermore, the need for air conditioning in the summer time in Canada, opposed to Europe and Sweden in particular, makes the ground source heat pump even more cost effective. Let us look at some temperature graphs.

It is not difficult to understand that different factors affect the dimensioning of a ground source heat pump. We talk about three dimensioning periods.

1. Regeneration period with recharged storage to each heating season.
2. The coldest day of the year, when the heating requires most power.
3. The total energy consumption of the heating system.

However, when we study the average temperature in Pitea (a Swedish city situated north of the Arctic Circle) and Montreal, we find that the winters are just as cold but that the summers are much warmer in Montreal, affecting the recharging of the energy source, with air conditioning having only marginal effects on the dimensioning of the energy source (Fig. 1).

In order to make our claims about ground source heat pumps believable, let us examine the technology we employ.

The concept is really quite simple. Right under our feet lies almost all the energy we will ever need to heat, cool and provide hot water for our homes and businesses.

These systems use a closed loop buried horizontally in the ground, or, where space is limited the ground collector may be installed vertically.

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A ground source heat pump can also be connected to a closed loop submerged in a body of water.

Any of these energy sources will also make an excellent energy sink for summer cooling needs.

So what are the opportunities and restrictions associated with using ground source heat pumps in urban areas.

The most obvious restriction would be the lack of space for a horizontal installation of the ground collector.

In spite of these, more than 60 per cent of all urban installations of ground source heat pumps are done horizontally. The reason for this is that ground source heat pumps use latent heat. If this would not be the case, a ground source heat pump would require approximately 50,000 sq. ft. for a regular installation.

Let us study two diagrams underlining the importance of dimensioning the ground collector correctly. Both these diagrams are based on data from a ground source heat pump installation in Montreal (Fig. 2).

The graph on top is called "wrong" depth. The ground collector is installed at a depth of approx. 1.7 m (5.5 ft) below the ground surface. It should be noted that the graph is showing the fourth heating season. The three preceeding heating seasons are computer simulated. When we reach January the fourth year, a frost body has been formed around the pipe in the month of June. Around the natural frozen soil, we will have a defrosting from March to April, due to the spring and summer sun, whereby the heat flux down in the ground gradually reaches the frost body around the pipe. In the month of July, we will reach the level of the pipe and the solar heat will then thaw the frozen soil around the pipe. The fifth heating season starts in October/November. We are now in a state where we, already in the beginning of the heating season, will start to form frozen soil around the pipe. This is the start to what we call perma-frost. If we allow the computer to continue this calculation with statistical values for another 20-30 years, the ground surrounding the pipe will be completely frozen.

With everything equal, apart from just one exception - the ground collector is installed at a depth of 0.9 m (3 ft). We can see how the natural frozen soil and the frozen soil around the pipe coincide in March/April. The spring sun defrosts the frozen soil and during the summer months the sun will reach the depth of the pipe. The ground collector is regenerated and we will start the fifth heating season without immediately freezing the soil and taking care of the latent heat.

All the above refer to the heating mode only. When we introduce space cooling to the system, the dimensioning has to be adjusted according to the cooling mode requirements.

Although we are injecting heat into the ground by using the heat pump for air conditioning in the summer, we still have to make sure that the ground is naturally regenerated, since we are extracting ten times more than we are injecting.

The heat balance which takes place on the ground surface in the summertime, can be illustrated by using an arrow diagram, where the solar radiation per square foot is approx. 25 times bigger than what you actually need to heat your building (Fig. 3).

The different loss factors affecting the heat balance or the heat flux on the ground surface are thermal radiation, convection, evaporation and reflection. The balance of this equation is the heat flux which enters the ground in the case of no heat extraction.

If we use a ground source heat pump system with this existing heat balance picture, we will find that in relation to the solar radiation, we are using a very small part, but in relation to the natural heat flux into the ground, we are using a considerable part. With a ground source heat pump system we will find a new balance temperature at the depth in the ground where the collector is buried.

Some technical aspects have to be considered when we are talking about ground source heat pump systems.

The thermal conductivity can be presented as a function of the moisture content in the ground, affecting the heat transfer and the heat loss in the ground. Our first observation is that the higher density, the better the coefficient of thermal conductivity and thermal capacity, making the refilling of the trench very important. Furthermore, if you go above a certain moisture content, frozen ground transfers heat better than unfrozen ground. Most soil types have a moisture content higher than 15 per cent (Fig. 4).

It is obviously important to know the water content in the ground in order to be able to correctly dimension a ground source heat pump system. The figure also shows that the water in the ground is the main heat transmitted (Fig. 5).

We know for a fact that the coefficient of thermal conductivity immediately surrounding the pipe is very important for a trouble free operation. This diagram illustrates that it is constant up to a distance of a few mm inside the compass of the pipe. Here, a wap transition occurs. It increases considerably just on the inside of the pipe through the

material and especially in the material on the outside of the pipe. When we are at a distance of approx. 24 mm from the center, we can see how t decreases by distance from the center (Fig. 6).

The above possibilities and restrictions mainly refer to horizontal ground source heat pump installations. Let us look into vertical ground source heat pump installations, systems which are and will be even more applicable to urban areas.

Cantherm's computer simulations and test installations, which also have been funded and monitored by the Ontario Government and the Enerdemo Program, clearly indicate that the efficiency does not improve by going vertical. The temperature of the ground source solution has the same yearly average temperature as any horizontal ground source heat pump installation. The reason for this is that 99 per cent of all energy extraction has to do with regeneration. Only a very small part of the extraction is actually geothermal energy.

This again underlines the importance of recharging the energy source. The only key to success and well operating systems is correct dimensioning of the energy source. There are no short-cuts.

Let us look at some slides illustrating the effects that different amounts of heat extraction have on vegetation.

So what makes ground source heat pumps the winners in the energy conservation race?

GROUND SOURCE HEAT PUMPS ARE GOOD FOR SOCIETY

An important factor to conventional heat systems is pollution. We know for a fact that pollution is taking place because we are using fossil fuels for heating homes and businesses. An energy management system based on a home-grown renewable energy source, utilizing only electricity, is a good start for tackling pollution in our society.

GROUND SOURCE HEAT PUMPS ARE GOOD FOR ELECTRIC UTILITIES

The "power" conservation qualities of a ground source heat pump system affect the production and distribution costs for the hydro producers.

In order to further illustrate this, we will take a look at a typical power profile for a 10 year old home in Montreal during a period of one year (Fig. 7).

If we were to write down the average temperature per day during a whole year, we would get the following graph. If we are using electric baseboard heating, we will have to add power exactly according to the graph. If we choose to use an air-to-air heat pump with auxiliary heating (electricity), we will get a power profile on the electric network corresponding to the middle line. At temperatures around $+0^{\circ}\text{C}$, the air-to-air heat pump stops and the auxiliary heating with its entire installation power goes on, requiring a power demand just as bit as an ordinary electric baseboard heating system. However, the utilization time will be shorter. If we use a ground source heat pump system, we can see that it already during the summer months gives a high performance factor and the closer we get to winter, the more the performance factor decreases. However, even during the coldest day, ground source heat pumps still have a COP of more than 2.5, and only demand 3-4 kW for the motors.

GROUND SOURCE HEAT PUMPS ARE GOOD FOR THE END-USER

Ground source heat pumps provide for much lower operating costs - up to 80 per cent less than any other conventional heating system.

Ground source heat pumps are capable of providing total comfort requirements - heating, cooling and domestic hot water.

Ground source heat pumps are adaptable to both forced air and hydronic heating systems.

Ground source heat pumps are 3-4 times more efficient than the most efficient gas furnace.

Last, but not least, ground source heat pumps are optimized for heating and designed for low temperature inputs, with cooling and air conditioning included in the system. Where cooling loads typically run 10-20 per cent of heating loads, it makes sense to design a machine with heating as a primary concern.

GROUND SOURCE HEAT PUMPS REPRESENT THE SOLUTION TO THE ENERGY PROBLEMS OF TODAY AND THE FUTURE.

FIGURE 1

THE THREE DIMENSIONING PERIODS

1. Regeneration period with recharged storage to each heating season
2. The coldest day of the year, when the heating requires most power.
3. The total energy consumption of the heating season

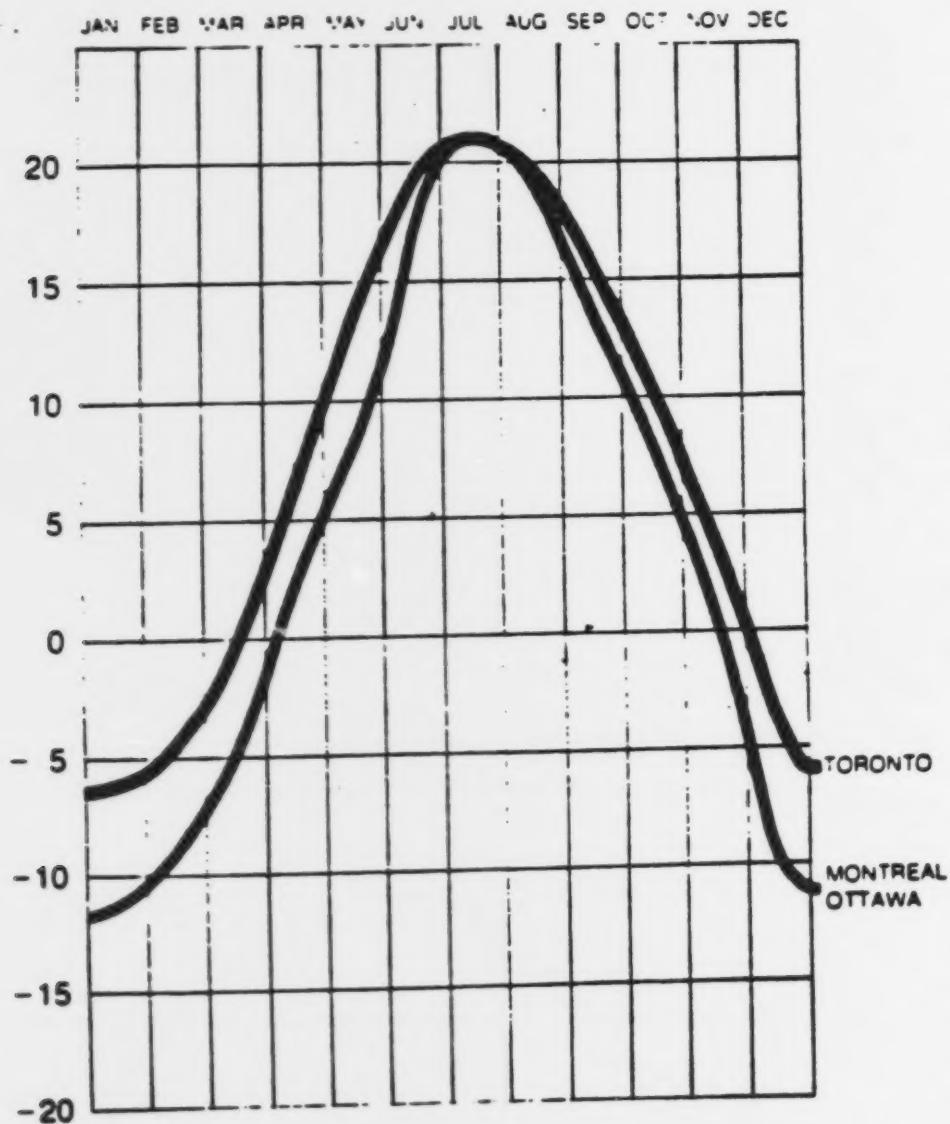


FIGURE 2

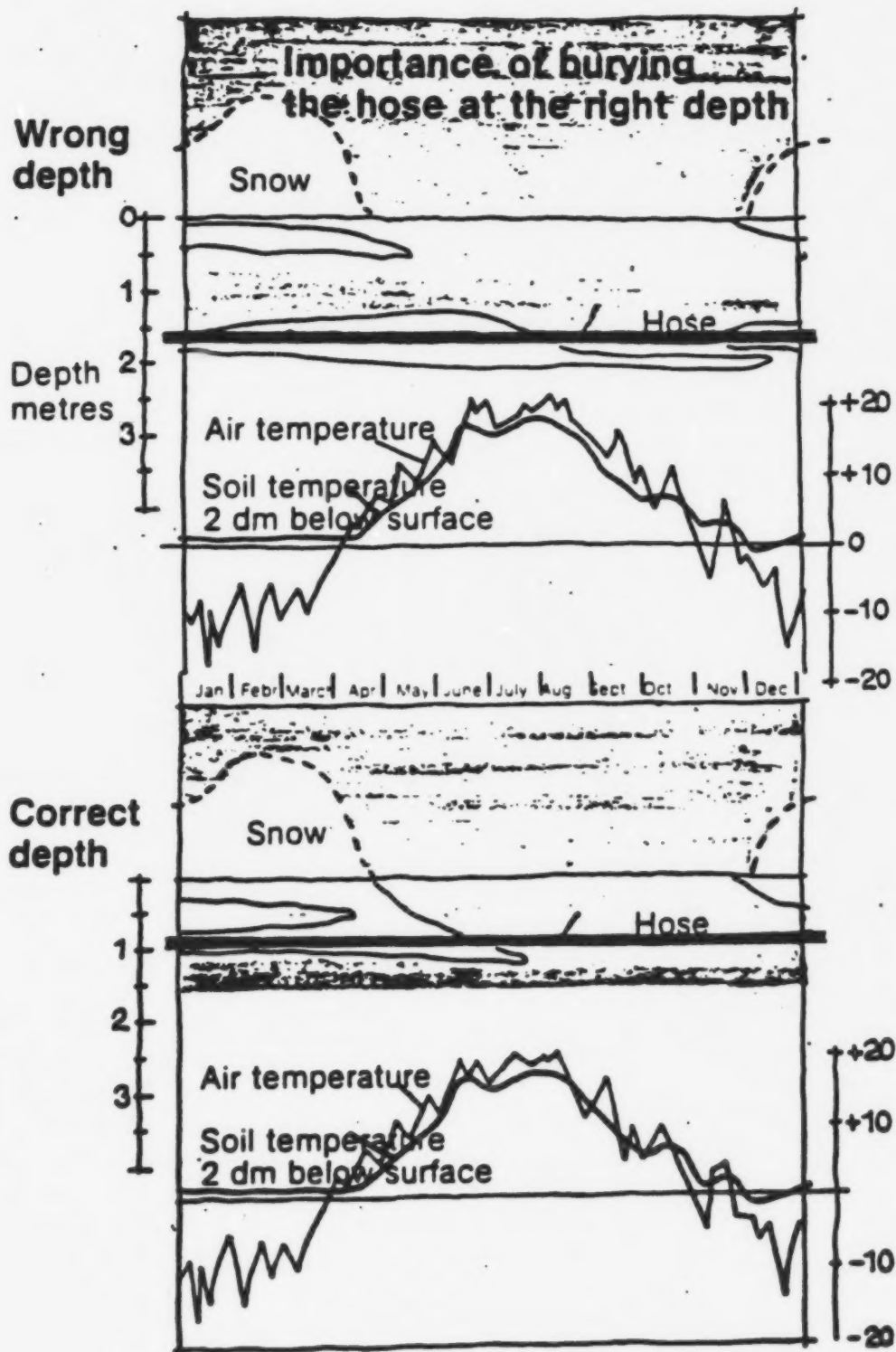


FIGURE 3

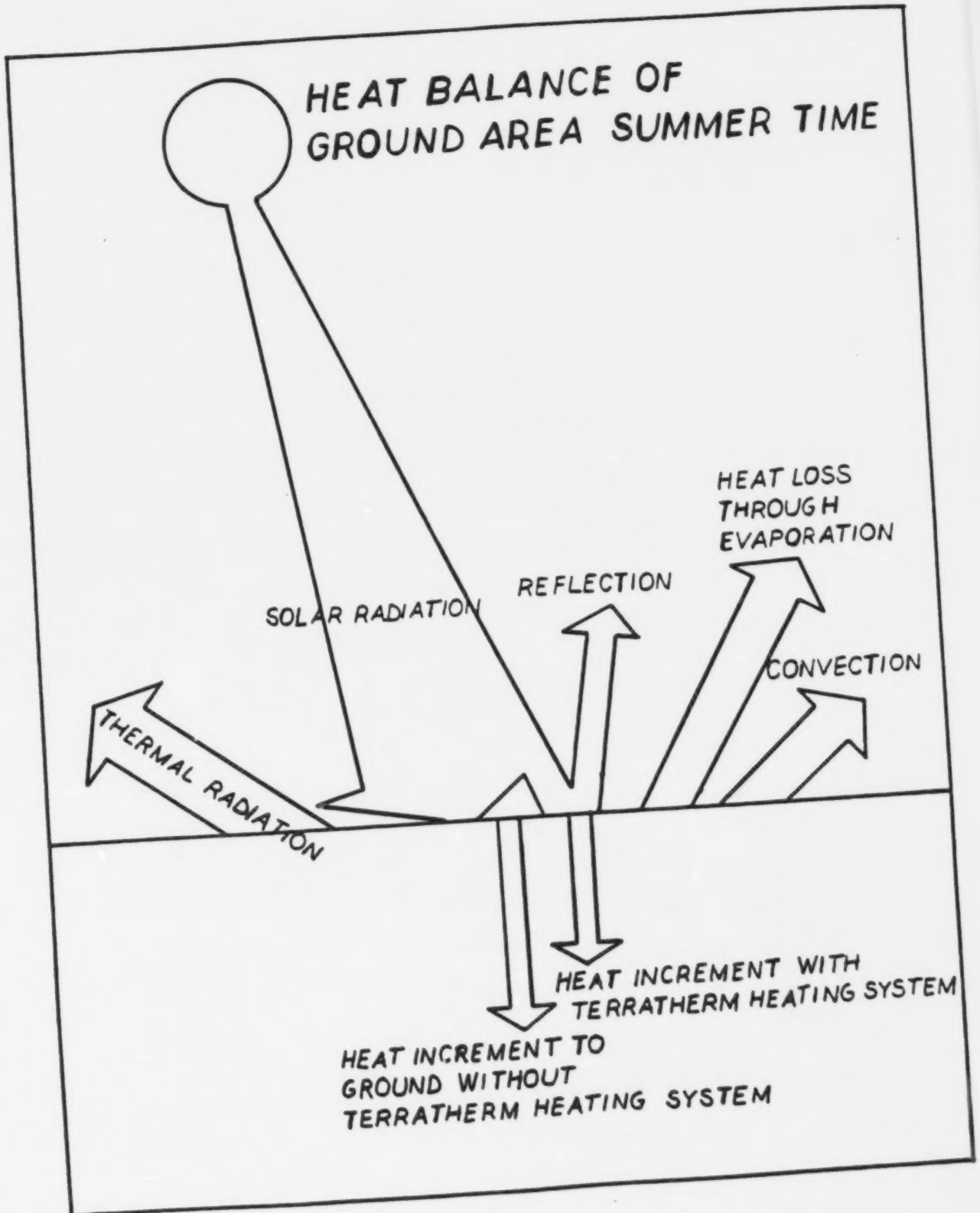


FIGURE 4

THERMAL CONDUCTIVITY FOR COARSE
GRAINED SOIL AS A FUNCTION OF
THE WATER CONTENT

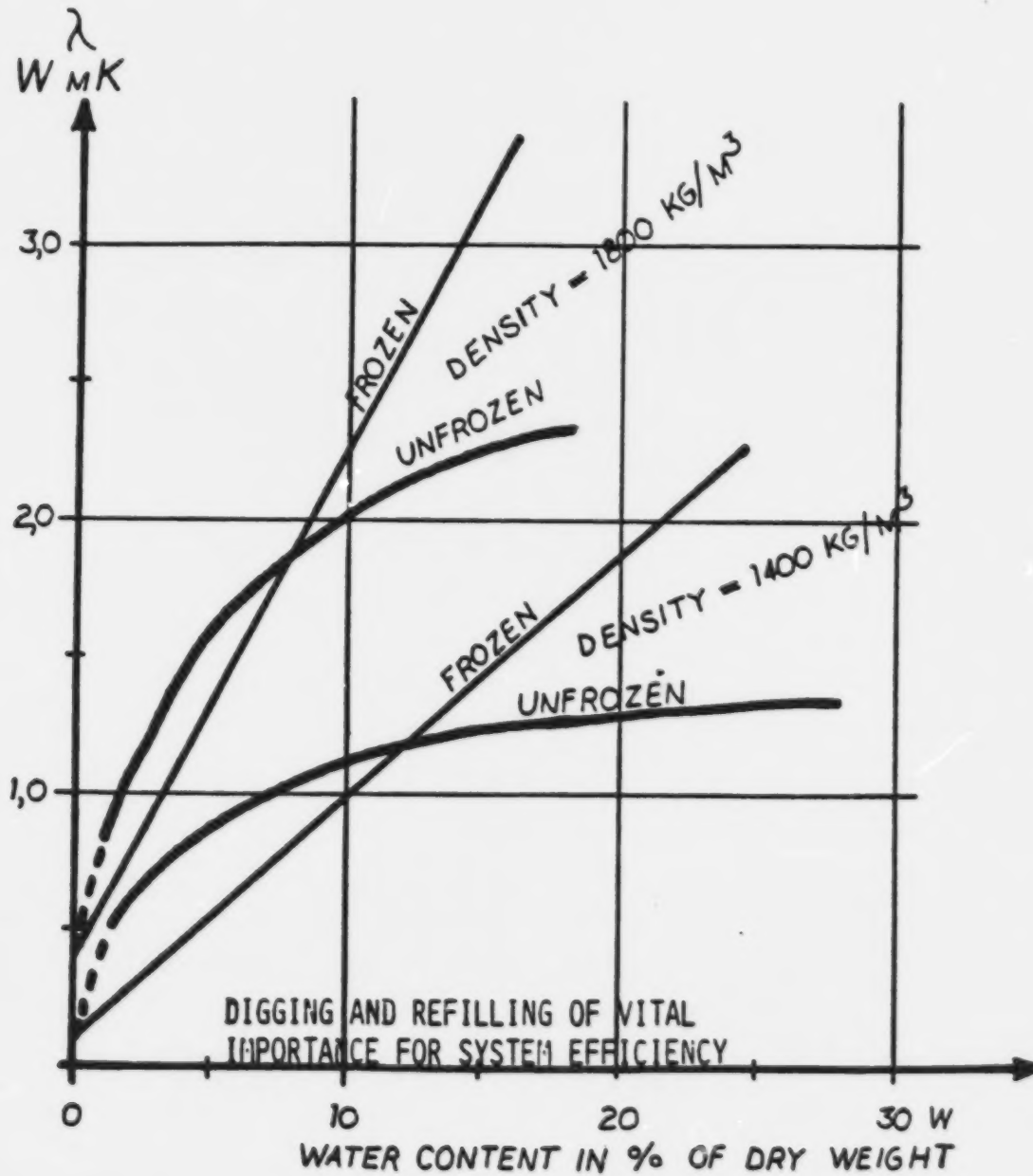


FIGURE 5

TERRATHERM HEAT SOURCE

REQUISITE SOIL VOLUME TO GIVE
12000 KWH WHEN COOLING DOWN
FROM +7°C TO -3°C AS A FUNCTION
OF THE WATER CONTENT

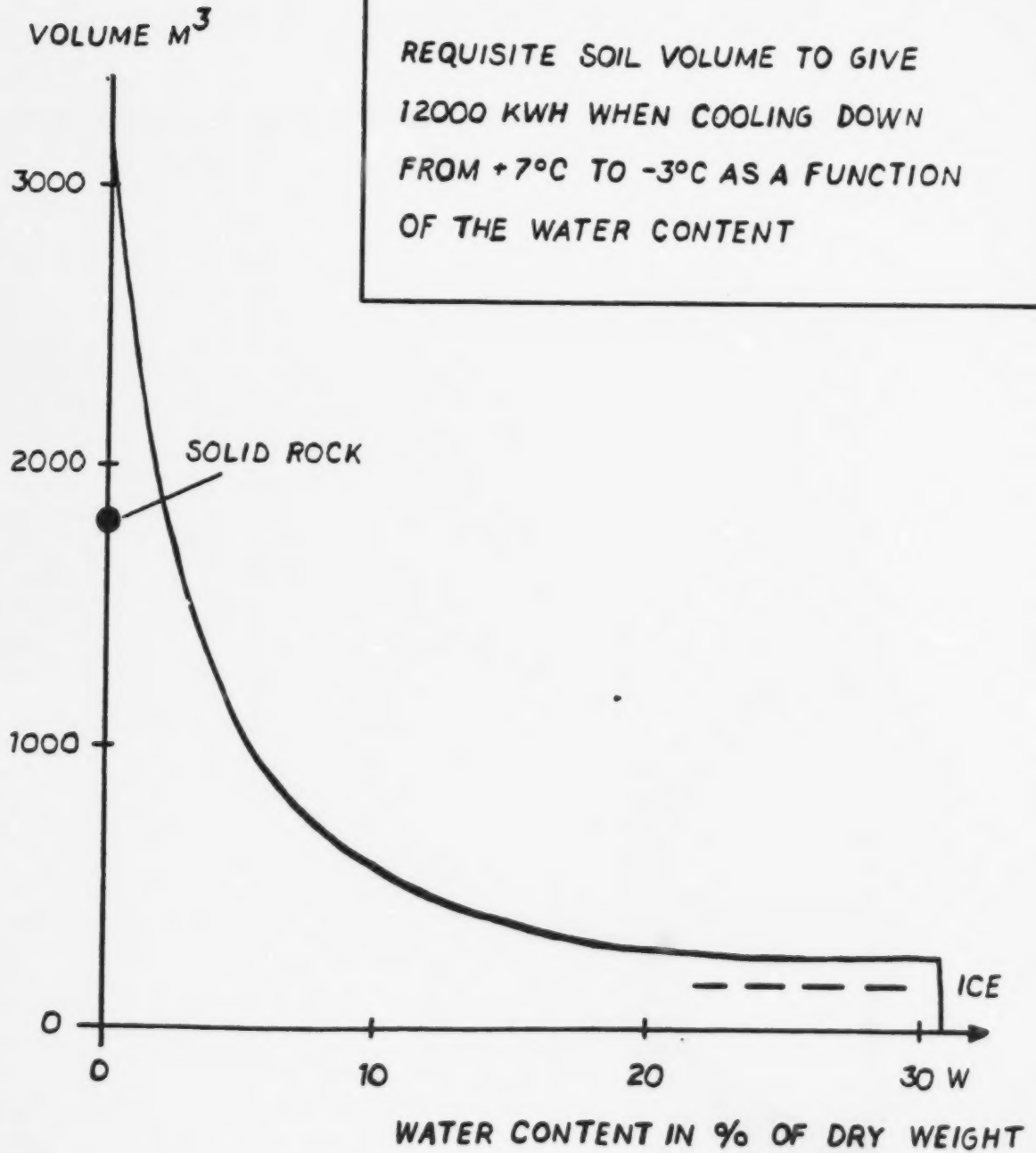


FIGURE 6

The ground nearest the hose is the most important. On the coldest day, we have most benefit from good thermal conductivity.

Temperature field around pipes.

Hose dia. 40/35, 8 kW for 300 m hose.

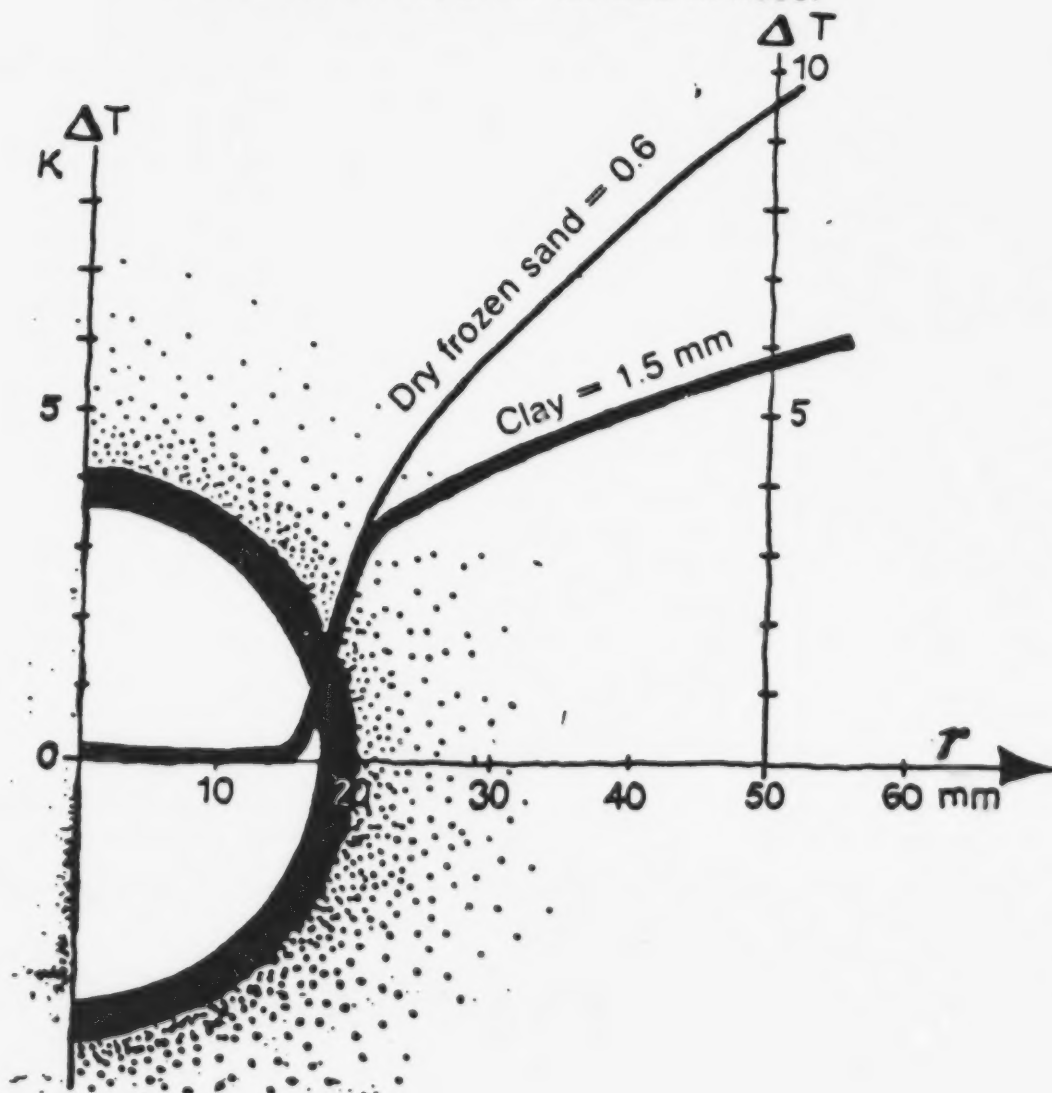
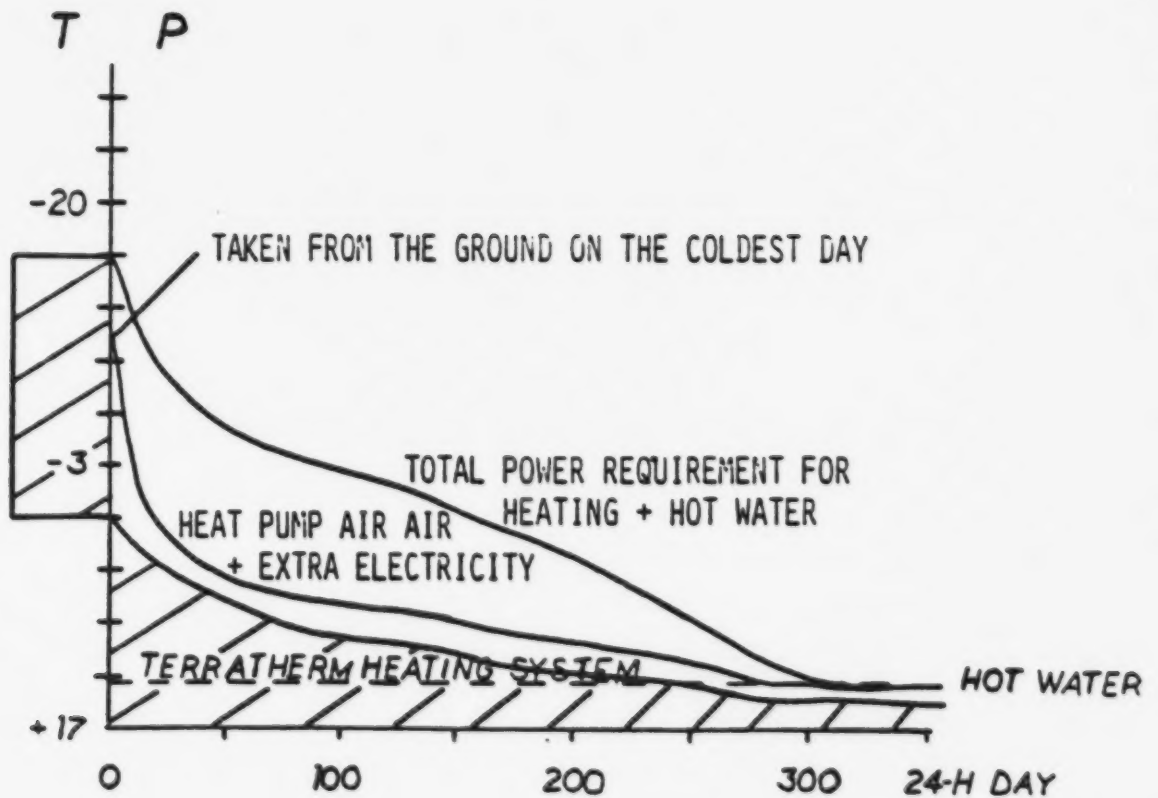


FIGURE 7

TYPICAL POWER REQUIREMENT PROFILE FOR
PRIVATE HOUSES IN THE 1960S/1970S IN
MONTREAL AREA DURING A YEAR



SPEAKING NOTES FOR
FLOYD D. MURPHY
PRESIDENT OF L. VILLENEUVE LIMITED

INSTALLING HEAT PICKUP SYSTEMS
FOR
EARTH COUPLED HEAT PUMPS

AIRPORT HOLIDAY INN
970 DIXON ROAD
FIESTA BALLROOM

JANUARY 10, 1985
10:20 A.M.

F.D. Murphy

Floyd Murphy is President of L. Villeneuve Ltd. and President of the Toronto chapter of H.R.A.I. He studied Electrical Engineering at the University of Alberta, and wide work experience includes employment with Northern Electric, Powers Regulator and Lennox Industries. Villeneuve Ltd. are one of the most active contractors involved in heat pump installations in the metro Toronto region.

INTRODUCTION

It is the installation of the heat pickup system portion of the earth coupled heat pump that sets it apart or makes it different from the air source heat pump.

It is the installation of the heat pickup system that is most likely to frighten off the average heating contractor and keep him from wanting to install earth coupled heat pumps.

The heat pickup system is a key component in the system and must be installed properly if full capacity and efficiency are to be attained.

The installation of the heat pickup system makes up 1/3 to 1/2 of the cost of the installation.

VERTICAL CLOSED LOOPS

Since over 60 per cent of our installations have been installed with closed vertical loops, I will concentrate on what we feel that we have learned to date with regard to the installation of vertical closed loops.

The first thing that we learned was that it was very difficult to get well drillers interested in drilling for us. We used 8 different drillers on the first twelve jobs that we installed. We had to talk to over 20 drilling companies in order to get the 8 who finally did drill for us, and then after we succeeded in getting agreements from them, we often had to wait up to four weeks longer than the date originally promised.

Our first few vertical loops were installed on properties that had mature lawns. The drillers did not take any precautions to protect the lawns and as a result, the lawns were badly damaged and it was quite expensive to restore them to their original state. We have now learned what precautions need to be taken when working on lawns, driveways, etc.

Once the holes were drilled, the next learning experience was that of inserting the tubing into the holes.

We have used 1" diameter polybutylene in parallel loops, 1 1/4" diameter polyethylene in series loops, 1 1/2" polyethylene in series loops and 1 1/2" polybutylene in series loops. Regardless of whether we used polyethylene or polybutylene, all joints were made by the fusion method. Our preferred piping material is 1 1/2" diameter polybutylene with the loops in series. There is a greater drilling expense with 1" diameter tubing and more labour related to hooking up the lines.

Since most of the holes are full of water from the drilling process, it is necessary to fill the tubing with water in order to reduce the bouyancy. Both polyethylene and polybutylene have a specific gravity of less than one. Because of this bouyancy, the tubing will float even when filled with water. It is a good practice to fasten a 100 lb. weight onto the bottom of the U bend before inserting the tubing into the hole.

We have found that the best procedure for inserting the tubing into the holes is to first wind two equal lengths of tubing onto a reel which is about 5' in diameter. We then fasten the U bend onto the ends of the polybutylene. Next we fasten a 100 lb. weight onto the U bend. We then strap a 10 ft. long 1" diameter steel pipe or a 10 ft. x 1" x 1/4" angle to the section of tubing directly above the U bend. A 7 ft. long 4" diameter concrete cylinder makes a good weight. The piece of pipe or angle iron is to straighten out the first 10 ft. of tubing so as to reduce the tendancy of the curve in the plastic to force the tubing against the wall of the hole. We then place the reel near the drilled hole and pull the tubing off of the reel and feed it down the hole. Feeding the tubing down the hole is not exactly a correct description because we usually have to push it down. Without the 100 lb. weight fastened to the U bend, it takes far more effort to force the tube down the hole and then it is also difficult to hold it there because it will float back up the hole unless tied off in some way at the top of the hole.

Because both the polyethylene and polybutylene try to retain a 5 ft. diameter curvature of the coil in which they are shipped, working with this material is like wrestling a giant Boa Constrictor. It seems to always want to coil up when we want it to be straight or else curve in a direction different than we want it to curve in.

It can be rather dangerous to work with the plastic tubing in the cooler weather. On several occasions I have seen it free from the reel or someone's grasp and hit a worker in the face with sufficient force to cut the skin. We used six men to get the tubing down the holes on some of our first jobs. Now we are able to do it with three men.

Returning to the problem of getting a driller, I would like to forecast drilling requirements for 1985. It has been estimated that of the 1000 earth coupled heat pumps which will be installed in Ontario in 1985, 600 will use a vertical closed loop system. This will require about 1800 drilling days. After allowing for winter shut down, weekends, rainy weather and breakdowns we can expect to get 155 days of drilling per rig. This means that in Ontario we would require 12 drilling rigs doing nothing but drilling for earth coupled heat pumps.

We either have to convince the drillers who are currently drilling water wells that there is good money to be made in drilling for earth coupled heat pumps or else convince new individuals or companies into the drilling business. Without the required drillers, we will not achieve the number of installations that we are predicting. We have found that some drilling conditions are best handled with an auger drill, others with water, and others with air. It would take a very versatile rig to handle all of the conditions that we run into.

As part of each vertical loop installation there is a 3 1/2 ft. deep trench required between the holes and the house. This trench can best be dug with a backhoe. Since two men generally have to get down inside the trench to make fused connection the trench should be about 2 ft. wide.

HORIZONTAL CLOSED LOOPS

We have installed several systems using horizontal closed loops and have generally found that in the Toronto area, a backhoe does the job better than a trencher. We have worked in areas where the surface looked ideal for a trencher but once we started digging we hit boulder after boulder that could only be moved with a backhoe. We have worked in sandy areas where the sandy walls kept caving in before we could get the tubing into the trench.

We have worked in wet areas where again the walls of a narrow trench would not stand up long enough to allow us to get the tubing into the trench.

We have generally preferred using polyethylene tubing in horizontal closed loops because we can get it in spools of up to 1500 ft. lengths which enables us to lay a complete horizontal loop with no joints on the exterior of the house.

The cost of installing a horizontal loop is about half the cost of a vertical loop system but the land area requirements generally restricts the horizontal loop to rural properties.

SPEAKING NOTES FOR
JAMES P. PHIMISTER, SENIOR HYDROGEOLOGIST
ROBERT G. McLAREN, M.Sc., HYDROGEOLOGIST
GARTNER LEE ASSOCIATES LIMITED

AN OVERVIEW OF
GEOLOGICAL CONSIDERATIONS
RELATED TO
GROUND SOURCE HEAT PUMPS

AIRPORT HOLIDAY INN
970 DIXON ROAD
FIESTA BALLROOM

JANUARY 10, 1985
10:20 A.M.

Mr. J. Phimister

Jim Phimister is a Senior Hydrogeologist with Gartner Lee Associates Ltd. of Markham. He was previously with Western Groundwater Consultants, of Winnipeg, as Mechanical Consultant on groundwater heat pump systems. His expertise is recognized in areas of heat transfer from Aquifers and geologic formations in Ontario.

INTRODUCTION

This paper is intended to present only a brief overview of some of the geological considerations that relate to the use of ground source heat pumps. Since about the mid-1970's, when alternate energy sources to fossil fuel became popular, there has been an enormous amount of geological research into the use of the earth as a heat source. The volume of literature is now fairly extensive.

THE EARTH AS AN ENERGY SOURCE

The earth acts as a giant solar collector storing thermal energy in the soil, rock and underground water. Below a depth of about 10 m, the shallow earth materials maintain a constant temperature of about 1-3°C above the mean annual air temperature for the locale. In Ontario, this means the temperature of the earth ranges from about 5-10°C from north to south.

By connecting a heat pump to the earth, some of the stored solar energy can be extracted. There are two basic methods used to connect a ground source heat pump. The first is to extend coils or loops from the heat pump and bury them either vertically or horizontally in the ground. This is often referred to as a closed loop or ground coupled system.

The second method is to pump ground water from a well to the heat pump and dispose of the water after heat extraction. This is often referred to as an open loop or ground water heat pump. Both the ground coupled and ground water systems can also provide cooling, if required.

Choosing the best method of connecting a heat pump to the ground depends on many factors including the type of heat pump used, the amount of heating/cooling required, and, very importantly, the geological conditions at the particular locale.

Whether a vertical closed loop system or a ground water system is used, a hole or holes must be drilled into the ground. For this reason, the geological materials to be drilled become critical, strictly from an ease of drilling standpoint. Obviously, for different diameters of holes, for different depths and for different materials there are appropriate drilling rigs. For example, a drilling rig capable of making 30 m deep, 100 mm diameter holes in stiff clay may not be capable of penetrating fine wet sand or stony till. In addition, a rig that can make a hole may not be capable of developing a water well.

ONTARIO'S GEOLOGY

This section will present a very generalized view of the geology of Ontario with particular emphasis on the availability of ground water. Ground water occurs to a varying extent in all geological materials. Those materials capable of yielding usable quantities of water are known as aquifers.

Geological materials can be divided into two main types -- (1) bedrock and (2) the unconsolidated material resting on the bedrock ("overburden"). The hydraulic and physical characteristics of the geological materials determine how ground water occurs and moves. In sand and gravel, which form some of the best aquifers in Ontario, water moves through the pore spaces between the individual grains.

Bedrock aquifers in Ontario yield water from cracks and fractures within the rock. There are many locations in Ontario where bedrock wells will yield 16 L/s or greater.

Overburden is thickest in the far north, southwestern and southcentral parts of Ontario. At many locations there are aquifers capable of yielding 1-4 L/s and numerous municipal and industrial ground water wells yielding 16 L/s or greater have been developed in the overburden.

In Ontario, there are thousands of water well records and borehole logs on file, particularly for the densely populated areas. These records give a reasonable indication of the geological materials encountered beneath the ground surface and, at many locations, water yield data is available. Although a great deal is known about the major aquifers in Ontario, geological materials are variable enough that water yields cannot be predicted with absolute certainty at any given location.

GROUND WATER FOR HEAT PUMP SYSTEMS

Water wells have been used to supply water for heat pumps where the used water is disposed of in sewers, ditches, streams or lakes. This is a wasteful use of ground water in most cases. Often, the extraction rate is greater than the natural recharge rate from precipitation and the aquifer become depleted. A better method is to return the used ground water to the same aquifer via another well. In this manner, there is no net consumption of water; only the temperature is altered. This type of system is often referred to as a well doublet, or production/recharge system.

One of the problems that may arise from this type of system is known as thermal interference. This occurs when recharged water migrates to the production well. It is important to understand this problem when contemplating the use of ground water for a heat pump. Although an aquifer may appear to be an infinite source of thermal energy to a small user, for systems using large volumes of water, it is possible to extract energy faster than natural cycles can replace it. This means that at some time after the system begins operation, the production water temperature begins to approach the recharge water temperature and the heat pump can no longer function.

The job of the hydrogeologist in designing a ground water system for heat pump use is similar to that of an engineer designing the mechanical system. However, one major difference is that a mechanical engineer can specify the equipment he requires and have it manufactured and installed according to design. The hydrogeologist has to work with a fixed and unseen heat exchanger -- the earth.

Some of the factors a hydrogeologist must evaluate in designing a ground water system are:

1. the aquifer thickness;
2. the aquifer porosity;
3. the aquifer heat capacity;
4. the aquifer hydrodynamic and thermal dispersion coefficients;
5. the thermal conductivity of the aquifer and the confining layers;
6. the water extraction and injection rate;
7. the injection temperature;
8. the available spacing distance between production and recharge wells;
9. the regional ground water flow direction and velocity; and
10. water quality.

Many of these factors can be estimated from existing information. Test drilling and test pumping are required to place values on other factors. Recently, computer models have been developed that evaluate hydraulic and thermal flow simultaneously. These models allow hydrogeologists to predict the thermal interference effect of a proposed design. From this, they can design a well spacing that will assure a properly operating system.

AQUIFER THERMAL ENERGY STORAGE - ATES

In heat pump systems that have both heating and cooling requirements, during certain times of the year cool water is injected into the aquifer and at other times warm water is injected. If the heating and cooling cycles are identical, there is no net change in the thermal energy stored in the aquifer. However, if the cycles are not balanced, the mismatch may have to be corrected by the addition of heat or chill.

For an ATES system, it is necessary to have a hot zone and a cold zone in the aquifer. During heating, water is extracted from the hot zone and, after the heat is removed, the water is injected into the cold zone. During the cooling cycle, the water is moved in the opposite direction.

ATES systems that have been operated in the U.S.A. have had energy recovery of 70-75 per cent on the first cycle and as much as 85-90 per cent by the fifth cycle. Storage of thermal energy in aquifers has been proven to be considerably less expensive than comparable storage tanks on many projects in the U.S.A.

Only a brief summary of some geological considerations in the use of ground source heat pumps has been presented in this paper. It is important that a qualified hydro-geologist be involved early in any ground source heat pump project. Using scientific principles, the hydrogeologist can assess the feasibility of the project and guide it to a successful conclusion.

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SPEAKING NOTES FOR

O.J. SVEC

NATIONAL RESEARCH COUNCIL

OTTAWA, ONTARIO

GROUND COUPLED SYSTEMS

- SYSTEMS AND DEVELOPMENT -

AIRPORT HOLIDAY INN

970 DIXON ROAD

FIESTA BALLROOM

JANUARY 10, 1985

10:20 A.M.

Dr. O. Svec

Otto Svec is with the Building Research Division of N.R.C. He is a graduate of the Slovak Technical University in Czechoslovakia. He worked with the Slovak Academy of Science, obtained a Ph.D. at the University of Waterloo and did research at teaching at Queens University. After working with a Geotechnical consulting company he joined the National Research Council. His involvements include Numerical analysis and methods, thermal problems in gas pipelines, heat storage and ground coupled heat pumps.

ABSTRACT

The efficiency of advanced ground heat exchangers and their potential for improving the economic competitiveness of ground coupled heat pumps have been evaluated. Advanced heat exchanger designs as well as some field performance experience are discussed.

INTRODUCTION

The major stumbling block for ground coupled heat pumps in breaking into the competitive market of heating/cooling systems, is the high cost of installed ground heat exchangers. In almost all current ground source heat pump installations, plastic tubing is used to draw the heat from the ground, because it is relatively inexpensive, easy to handle, easy to join, and noncorrosive. The thermal conductivity of plastics, however, is so low that very long horizontal or vertical ground loops are needed in order to deliver the required heat. The long length is easier to tolerate in horizontal systems, where installation is simple and less costly, than in vertical systems. As this paper deals only with vertical ground heat exchangers, discussions of horizontal versus vertical installations are not included.

The main objective of the research work undertaken at NRC is to seek an economic alternative to the vertical plastic tube heat exchanger. Such an alternative in ground heat exchangers, characterized by higher efficiency and different operating strategy, might improve the market potential of ground source heat pumps.

PROBLEM STATEMENT

The cost of the installed vertical ground loops is about 30-50 per cent of the cost of the entire system. If efficiency of the ground loop can be improved by better design and by lowering the operating temperature, then the loop length can theoretically be reduced by 50-80 per cent, Table 1. This would reduce the cost of the entire system by 15-40 per cent. Ground coupled heat pumps could then become a competitive alternative.

To investigate the performance of a heat exchanger; performance which in fact determines the length required to deliver the necessary heat energy, all factors have to be investigated: material, design, flow of the circulating fluid, operating temperature, operating strategy and, of course, cost of drilling. The first two items, material and design are very important. The performance of single plastic and metal pipes,

as well as a flexible liner, are compared in Figure 1; it is evident that the amount of heat flux can be substantially increased depending on the material used as well as heat exchanger design. Influence of flow (laminar or turbulent, depending on its velocity) of circulating fluid is demonstrated in Table 2. The overall performance depends to a certain degree on boundary layer and corresponding heat transfer coefficient. Operating temperature as well as operating strategy (cycling), are also of great importance.

METHODS

The specific objectives of this program are to improve the performance of ground heat exchangers by (a) optimizing design to allow more effective "circulating fluid-ground soil" heat exchange and, (b) using lower operating temperatures to obtain the benefit of larger temperature differences and, under freezing conditions, of the latent heat of fusion. Better performance through improved design had already been demonstrated in the laboratory (2) where promising results in terms of larger heat flux were obtained. Laboratory conditions are, however, rather ideal and such results cannot be simply extrapolated directly to the field situation.

The second factor, using lower circulating fluid temperature, was also investigated by computer modeling (3). Lower operating temperatures will allow shorter exchanger length, but they also cause some decrease in the seasonal performance factor (SPF). The example taken from Ref. 3 and shown in Table 1 indicates that trend. These results, however, are considered to be overly optimistic (length reduction from 400 m to 70 m due to decrease of brine temperature from +3°C to -7°C). Full-scale testing under natural field conditions was needed not only to confirm the above findings, but also to obtain information on other questions such as recharging, soil structural integrity after thawing, and effect of cycling.

TESTING FACILITY

A full description of the testing facility is presented in Ref. 4; only its main features are mentioned below.

The test facility consists of three 15 m deep heat exchangers and a heat pump refrigeration system using a thermally conditioned water-glycol solution. The refrigeration system has a three-stage thermal control: a refrigerant bypass on the heat pump, a mixing valve connecting the main loop and the return from the heat exchangers, and electric heaters at the top of the heat exchangers providing final, very fine adjustments. All three stages are individually controlled.

The current testing program was undertaken to evaluate the relative effectiveness of two new heat-exchanger designs with respect to a benchmark 3.75 cm diameter U plastic pipe commonly used in field applications and, in particular, to determine if such new systems have an economic advantage. For this purpose rather simple steady-state and transient tests using a step-wise cooling function are being conducted at this time.

HEAT EXCHANGER DESIGN

Each heat exchanger was placed in a 30 cm diameter hole, 15 m deep augered in soft clay soil and instrumented with thermistors at three locations: bottom, middle and top. After the exchanger was positioned as symmetrically as possible, the hole was backfilled with sand, which was saturated by the high natural water table. Since saturated sand has approximately three times the thermal conductivity coefficient of the clay, such an arrangement responds thermally like a large (30 cm) pipe. As can be seen on Fig. 2, the first heat exchanger is a straight 3 cm steel pipe with four 12.5 cm longitudinal fins, the second is constructed of four 1.25 cm copper pipes, and the third is the plastic 3.75 cm U-tube serving as a benchmark.

RESULTS AND CONCLUSIONS

The full-scale experimental program commenced only recently, hence, only a limited number of results have been obtained so far. These results are very interesting and encouraging. We feel that the direction and concept of our research is promising. Since the quantitative results are just being recorded at this time and since their analysis will be published in (4) shortly, only some observations and tentative conclusions will be given here.

- (a) It is clear that at lower operating temperatures the heat exchanger extracts more heat from the ground. The main benefit of using a low temperature is a reduction of the length of the heat exchanger while its disadvantage is a small SPF reduction.
- (b) Copper or steel heat exchangers are much more effective than plastic tubes if performance is compared on the basis of equal contact fluid-heat exchanger area. However, if the cost of a running meter of a large contact area plastic tube is similar to that of a small contact area metal heat exchanger, then the advantage of the high conductivity of metal may not be realized. This is true, particularly at high operating temperatures (+3°C to -6°C).

- (c) In steady-state at above freezing temperatures and at a slow fluid flow (below 10 l/min), plastic, copper and steel-finned heat exchangers have similar overall performance.
- (d) In steady-state at just below freezing temperatures and at moderate fluid flow (20 l/min), the heat gain from the copper heat exchanger is up to twice the gain from the plastic U-pipe.
- (e) In a transient situation, Fig. 3, the copper heat exchanger has a considerably better performance than the plastic pipe.
- (f) To utilize the potential of an advanced heat exchanger, operating conditions have to be adequately demanding. In other words, at high fluid temperatures and low velocity the quality of the heat exchanger becomes unimportant.

To draw additional conclusions as to the economic advantage of the new heat exchanger designs requires more testing at lower fluid temperatures (-3, -7 and -10°C) and higher fluid flow (40-50 l/min).

I would like to use this opportunity to thank the organizers of this workshop for inviting me to speak to you about some of the research done in the NRC in the area of ground coupled heat pumps. To conclude, the main thrust of our work is to investigate whether there is an economic alternative to the plastic tube designs commonly used today, an alternative which might lead to a breakthrough in the market for ground coupled heat pumps.

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TABLE 1

LENGTH OF THE GROUND LOOP AS A FUNCTION
OF OPERATING TEMPERATURE (REF. 3)

OPERATING TEMPERATURE		3°C		-7°C	
CLIMATE		LOOP-LENGTH	SPF*	LOOP-LENGTH	SPF*
(a) without recharging					
Cold		450 m	2.65	73 m	2.35
Moderate		145 m	2.70	45 m	2.40
Warm		57 m	2.85	27 m	2.55
(b) with recharging					
Cold		440 m	2.68	72 m	2.50
Moderate		140 m	2.80	43 m	2.65
Warm		53 m	3.15	25 m	2.90

* SPF = Seasonal Performance Factor

TABLE 2

EFFECT OF FLUID BOUNDARY LAYER (REF. 5)

$$p = 0.43 \text{ W/mK}, \quad g = 2.0 \text{ W/mK}$$

Heat Resistance Composed	Fluid Temp. °C	Fluid Velocity m/s	Heat Transfer Coefficient W/m ² K	Q W/m	% of Case 1	% of Case 2
Soil (Case 1)	-	-	-	1.70	100.0	-
Soil and tube wall (Case 2)	-	-	-	1.18	69.4	100.0
Soil and tube wall and fluid	0°C	0.2	106	0.70	41.2	59.3
		0.5	1104	1.11	65.3	94.1
		1.0	2245	1.14	67.0	96.6
	-12°C	0.2	102	0.69	40.6	58.5
		0.5	118	0.73	43.0	61.9
		1.0	1329	1.12	65.9	95.0

SPEAKING NOTES FOR
C.B.H. CRAGG, M.A.Sc., P.Eng.
CIVIL RESEARCH DEPARTMENT
ONTARIO HYDRO

SELECTION OF DRILLING METHODS
FOR THE
INSTALLATION OF GROUND SOURCE HEAT PUMPS

AIRPORT HOLIDAY INN
970 DIXON ROAD
FIESTA BALLROOM

JANUARY 10, 1985

10:20 A.M.

Dr. C.B. Cragg

Chris Cragg is a Civil Engineer with Ontario Hydro Research Division. He has a master's degree in Geotechnical Engineering, and has been involved in numerous subsurface exploration and instrumentation installations for Ontario Hydro construction and research divisions. He was previously employed with a Geotechnical consulting organization.

OVERVIEW

Ideally selection of drilling equipment for heat pump installations should consider four factors. These are geology, site conditions, environmental impact and economics. Components of these factors are described and their role in drill selection is discussed.

INTRODUCTION

Selection of drilling equipment for heat pump installations is difficult for many mechanical contractors because it is outside their sphere of experience and, currently, the choice may be limited. Other speakers at this seminar have discussed some of the difficulties involved in successfully installing the ground coils. This contribution will outline the factors that should be considered in selecting the drill equipment and method. These factors are:

- geology
- site conditions
- environment
- economics.

GEOLOGY

The geology factor can be further divided into three components:

- overburden
- bedrock
- water.

It is important to know ahead of time what type of conditions are likely to be encountered in drilling at a particular site so that proper drill equipment is brought to do the work. The thickness of overburden and the presence (or absence) of boulders will determine the ease of drilling a hole. In Toronto overburden thickness ranges from about 25 feet at the lakeshore to over 100 feet north of Bloor Street. Soils may range from sands, which are easy to drill, to very dense glacial tills, which are much harder to drill.

Ontario contains a wide variety of rock types and qualities. These range from the hard granites of the Canadian Shield to the soft shales found around Toronto and Oakville. Hard rock drilling can be much slower and wear out equipment, such as drill bits, much faster than drilling softer rocks.

Water is a critical element. It is a major factor determining whether a hole will stay open or cave in. A high water table in a sandy soil usually dictates the use of a casing or drilling mud to keep the hole open until the ground coil is installed.

Information on these factors is currently available from surficial geology maps, engineering geology maps, bedrock topography maps and water well records. All these pieces of information are publically available through the provincial governments. Local experience on the part of the drilling contractor is also a valuable source of knowledge.

SITE CONDITIONS

Four items should be considered under site conditions when selecting drilling equipment:

- access restrictions
- overhead obstructions
- underground services
- landscaping/slopes.

In areas of older housing narrow spaces between dwellings may limit the size of equipment that can enter the backyard. Trees, utility poles, overhead wires, fencing and landscaping may also discourage the entry of larger drilling equipment to the site.

In choosing the drilling locations on the site, a spot that is accessible, free of overhead and underground hazards is required. Locations of gas, sewer, water, telephone, hydro and tile beds should be checked before drilling. Subterranean building extensions should also be investigated.

Besides limiting access routes to the site landscaping may also limit the locations in which holes can be drilled. Equipment supplied with hydraulic legs, front and rear, speeds set up time and facilitates drilling on sloping ground.

A preliminary inspection of the site by the prospective drill contractor can avoid many of these problems.

ENVIRONMENTAL FACTORS

The drilling equipment and drill method can have three effects on the local environment (including the owner and the owner's neighbours):

- noise
- site damage
- waste material.

The noise level generated by the drilling equipment may have adverse effects on developed neighbourhoods or on the heat pump installer's staff. Percussion drills can be extremely noisy unless downhole hammers are used. Hydraulic rotary equipment can be comparatively much quieter.

Drill equipment can be trailer mounted, or self propelled. Self propelled units may ride on standard truck tires, crawler tracks or balloon tires. Each variation of drill will have a different weight and effect on the site. The damage to the site will depend on the pressure exerted on the ground by the tires or tracks, the ability of the vehicle to turn without tearing the ground surface and the weather. Selection of equipment to minimize site damage is most critical in the spring or after heavy rainfall. Planking or military landing mats can be used to support vehicles where soft ground situations cannot be avoided.

In all ground coil drilling operations, soil or rock is removed from the hole and is not put back in. Augering produces a pile of cuttings which is usually easily manageable. Percussion drilling also produces manageable cuttings. Wash boring produces sediment and a large quantity of waste water to be channeled away. Several hundred litres of bentonite (clay) slurry are the residue of mud drilling. This may be the hardest waste to clean away, particularly at previously developed sites.

Attention to minimizing environmental effects can save the contractor money in the form of clean up and repair costs. It can also create a favourable image for the industry, promoting more heat pump installations in the same area.

ECONOMIC FACTORS

Once the equipment choice has been narrowed to drills that can get on the site and can cope with the anticipated subsurface conditions, a final selection can be based on economic factors. These include:

- equipment cost
- cost and service life of drilling tools
- materials
- labour
- licensing
- mobilization and set up time
- productivity

Drilling equipment is expensive to purchase, with most units generally ranging from \$50,000 to \$500,000 or more, exclusive of drilling tools. Equipment maintenance and retention of competent operating staff have been such substantial burdens to most local geotechnical engineering consulting firms that virtually all of them have folded their drilling divisions and now rent from drilling specialty companies. When renting be sure to check what is and what is not included in the price. Hourly rental of a well drilling rig may be in the order of \$120 to \$150 while that of an augering/diamond drilling machine may be \$60 to \$75. These rates usually include the cost of operating personnel but mobilization to the site, tools worn on the site and materials used are normally extra.

Drilling tools are more likely to wear out in rock or bouldery soil and in hard (metamorphic/igneous) rock rather than soft (sedimentary) rock. These tools include tricones, casing shoes and diamond coring bits. This cost should be considered when pricing each job.

In caving ground casing or drilling mud may be needed to keep the hole open until the ground coil can be installed. Cement may be required to plug artesian water flows. These materials may add to the price of the job.

The number of people involved in drilling the holes should be considered. While a drill can be operated by one person many operations are best done by two people, such as pulling the drill string or installing the ground coil. This may mean pulling a crew member from some other part of the heat pump installation to help in critical operations. The productivity of the drill crew may be improved by supervision or by paying on a footage rather than a hourly basis.

Certain types of drilling contractors, such as well drillers, must be licensed. This affects the rental price. It is also an obstacle to using a well drilling rig should your firm elect to purchase one.

In selecting rental drill equipment, mobilization costs may be significant. These changes are usually based on distance from the contractor's shop to the job site. Mobilization costs can be reduced by scheduling several installations in the same location concurrently. Set up time varies with type of equipment and choice of drilling method. This "non productive" time adds to the length and cost of the job.

Productivity is only one factor determining the cost per metre of hole drilled. All the other costs - mobilization, set up, tools, materials and supplementary labour - determine the real productivity and unit costs associated with the ground coil installation.

SUMMARY

Full consideration of all the equipment selection factors is currently limited by the availability of equipment. The available equipment has been specialized for soil sampling, well drilling, blast hole drilling, placing gas pipe and other purposes other than installing heat pump ground coils. As the demand for heat pump installations yeilds more work for drilling contractors, drilling equipment will be modified or created to suite the needs of the heat pump industry. This should improve the choice and efficiency of the drill equipment available to the heat pump installer.

SPEAKING NOTES FOR
H.S. RADHAKRISHNA, PH.D., P.ENG.
CIVIL RESEARCH DEPARTMENT
ONTARIO HYDRO RESEARCH DIVISION
TORONTO, ONTARIO

IMPORTANCE OF THERMAL PROPERTY MEASUREMENTS
FOR
GROUND SOURCE HEAT PUMPS

AIRPORT HOLIDAY INN
970 DIXON ROAD
FIESTA BALLROOM

JANUARY 10, 1985
10:20 A.M.

H.S. Radhakrishna

"Krish" Radhakrishna has a Ph.D. degree and specializes in soils and soil thermal behaviour in the Ontario Hydro Research Division. He has done special work on underground power cables, nuclear waste disposal in geologic formations, ground freezing and ground coupled heat pumps.

OVERVIEW

Environmental factors and the ground characteristics have to be considered in the design of a ground source heat pump system. Interaction of these various factors and their assessment are outlined. In particular, the method of obtaining the thermal properties of the ground are described.

INTRODUCTION

The theme of this workshop is utilization of ground as a heat source in the heating season and as a heat sink in the cooling season. This is done by employing a heat pump which can upgrade the low temperature heat to a higher temperature heat. Thus a ground source heat pump will be made up of 3 sub-systems; namely

- ground collector system
- heat exchange system
- distribution system.

In order for the coupled system to perform efficiently the extracted heat should be at as high a temperature as possible so that the upgrading needed at the heat pump is reduced. Also the extracted heat energy is replenished during the warmer season either by natural process or assisted by the heat rejection cycle.

The extent and rate at which thermal energy can be extracted and rejected to the ground is determined by:

- environmental factors
- ground characteristics
- configuration and size of the ground collector system.

Alternatively, the configuration and size of the ground collector system is designed in such a way as to maximize the heat extraction from the ground for the given set of environmental and ground conditions. Figure 1 shows interrelationship between the various factors that are to be considered in the design of a ground source heat pump.

ENVIRONMENTAL FACTORS

The weather dependent parameters such as air and ground temperatures, snow cover, frost depth and precipitation have a profound effect on the performance of the ground collector system. One of the advantages cited for the ground source heat pump is that the ground temperatures are warmer than and fluctuate far less than air temperature.

Figure 2 shows the field recorded data by the National Research Council of Canada for a site near Ottawa, Ontario. This data suggests that below a depth of 5 m the soil ambient temperature is fairly constant with seasons. (1)

Climatic parameters such as air temperature or degree-days, wind and solar radiation also influence the energy demand in the case of space heating (Figure 1).

GROUND CHARACTERISTICS

The following ground parameters are to be considered in designing the arrangement of ground collector systems and sizing of the heat pump.

Soil and Bedrock Stratigraphy

A good description of the soils and bedrock stratigraphy is necessary not only for the purposes of characterizing the thermal properties of the ground but also for installing the ground collector system. This information is obtained from well records or regional soil maps.

Ground Water Table

The position of ground water table and its variation with season is important as the ground water acts as a good heat source and also effects the thermal properties of the ground.

Surface and Subsurface Drainage Conditions

Surface drainage is important for the shallow-buried horizontal pipes. Subsurface drainage will affect the heat balance in the ground and especially the replenishment of heat from a distant source.

Thermal Properties of the Ground

Ground as a composite body of mineral matter and water will store and conduct heat. While the heat capacity determines its ability to store, release or absorb heat, the thermal conductivity determines its ability to transfer heat from warm to cold regions.

Thermal conductivity and heat capacity of soils and rock exhibit a marked difference in their frozen and unfrozen state. Frozen soils are generally better conductors and have slightly higher heat capacity. A significant amount of latent heat is absorbed or released during the phase change of its pore water.

In unsaturated horizons of the soil stratigraphy the thermal conductivity is highly dependent on the moisture content or degree of saturation. Thus the horizontal ground collectors installed at shallow depth can experience a marked change in thermal behaviour of the ground. Also the frost line will be depressed and in some situations a permafrost condition may result.

THERMAL MODEL

The process of heat extraction and rejection into the ground is fairly complex involving heat and mass transfer including phase change of pore water in the ground. Efforts are being made to model these coupled processes using numerical analysis techniques. Notable among these are the finite element, finite differences and boundary element methods. The computer code TRUCHAM which models the coupled heat and moisture flow through the ground can handle complex boundary conditions and solutions can be sought in 2-D or 3-D fields. (2) This code has a potential for adoption to the problem of ground source heat pump. Several other models developed in other areas of applications may also be adopted for this purpose. The purpose of these models would be to carry out a parametric study of the variables described above and to provide the sensitivity parameters, for optimizing the design. In order to achieve this a good data base for thermal properties of the ground is essential.

Measurement of the Thermal Properties

In situ measurement of thermal properties of ground on a routine basis has only come into practice recently. In the case of power cable installations it is a norm. The technique has been perfected and fully automated with the development of thermal property analyzer (TPA). (3) It is a microprocessor based instrument that can measure the thermal conductivity and diffusivity parameters in about 10 to 15 minutes.

The thermal probe consisting of an electric heater element and the temperature sensors is inserted into the ground at the desired location and at desired depth. After the probe reaches thermal equilibrium with the surrounding media, a constant power is supplied and the temperature rise of the probe is monitored. The data is recorded automatically and the thermal parameters (conductivity and diffusivity) are calculated internally. These values along with the coefficient of fitness of data to the theory are displayed at the end of 100 secs.

Thermal probes with temperature sensors at multiple locations on the probe have been used to obtain the property measurements with depth by a single test. Also probes of varying sizes (3 mm to 25 mm diameter and lengths of 1 m to 5 m) have been used.

These probes have also been used for monitoring the seasonal changes in thermal properties of the ground at one of the horizontal ground source heat pump installations at Nobleton, Ontario. (4)

CONCLUSIONS

Environmental factors, ground characteristics influence the performance of the ground source heat pump. Modelling of the thermal processes of heat extraction and rejection is needed to rank the various factors and to aid in optimizing the ground collector system.

A wealth of experience in measuring and monitoring the thermal properties of ground now exists - it can be exploited for the design of ground source heat pumps.

With the increased use of TPA it is possible to create a good data base on a regional basis, that can be used by the heat pump contractors with confidence.

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1. C.B. Crawford and R.F. Legget. "Ground Temperature Investigations in Canada". Engineering Journal, March, 1957.
2. H.S. Radhakrishna, K.C. Lau and A.M. Crawford. "Coupled Heat and Moisture Flow Through Soils". Journal of Geotechnical Engineering, ASCE, Vol 110, No. 12. December 1984.
3. S.A. Boggs, F.Y. Chu, H.S. Radhakrishna and J. Steinmanis. "Measurement of Soil Thermal Properties - Techniques and Instrumentation". IEEE Transaction on Power Apparatus and Systems. Vol PAS-99, No. 2. March/April 1980.
4. F.J. Lenarduzzi. "Monitoring Results from Operating Systems". Paper presented at Ground Source Heat Pump Workshop. Toronto, January 10, 1985.

FIGURE 1

GROUND-COUPLED HEAT PUMP THERMAL MODEL

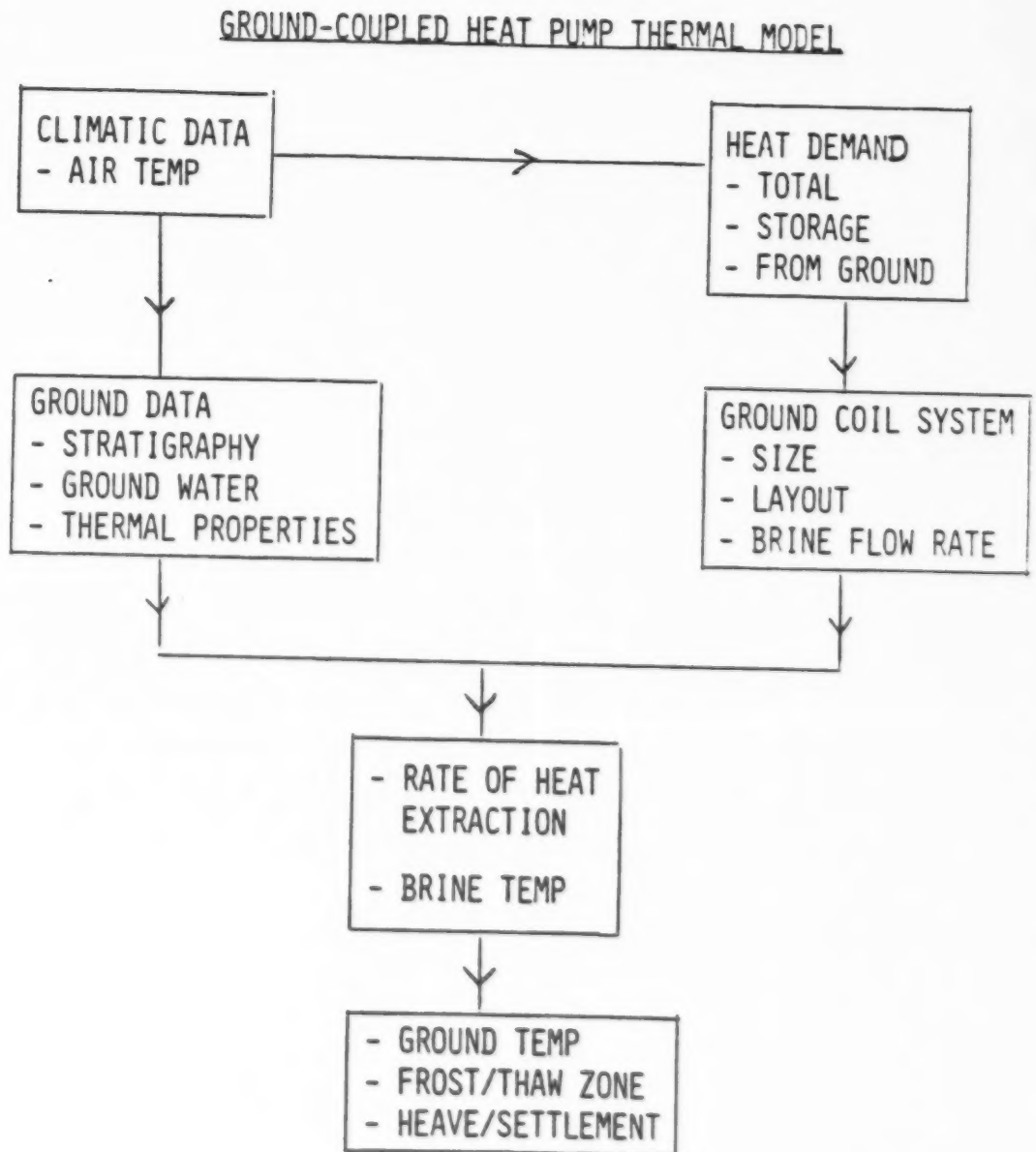


FIGURE 2

MONTHLY AVERAGE GROUND AMBIENT TEMPERATURES KNOBLAKE

FROM OCTOBER 1954 TO SEPTEMBER 1955

(CRAWFORD AND LEGGET, 1957)

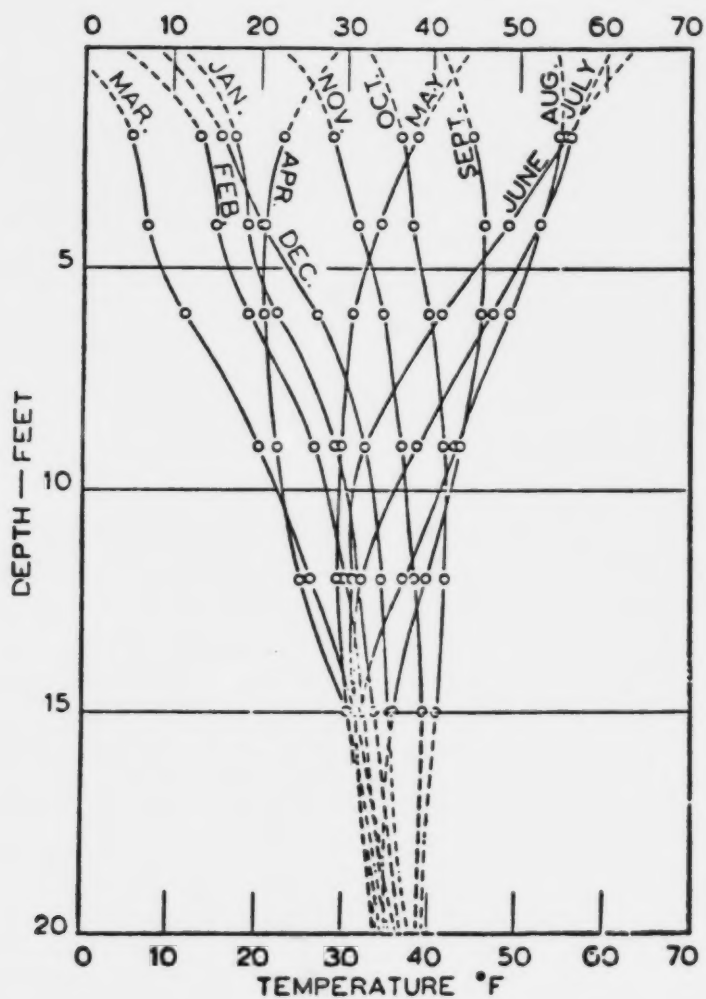
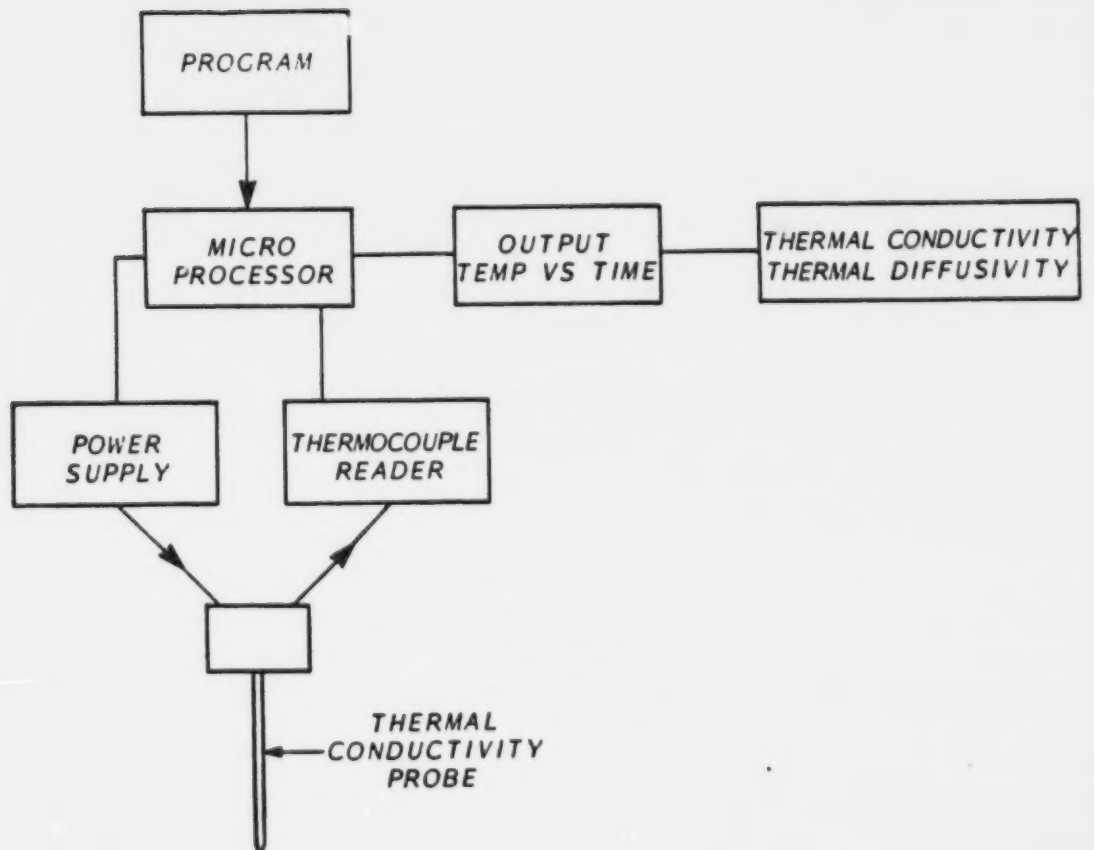
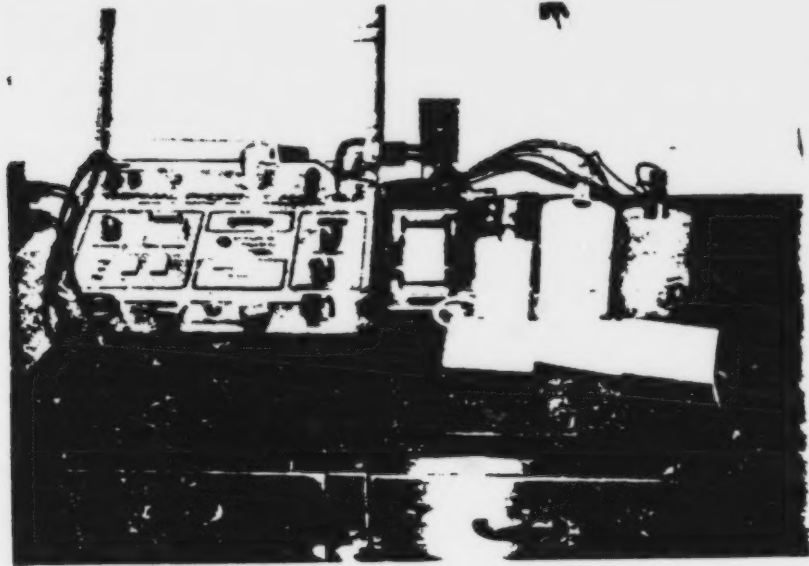


FIGURE 3

TRANSIENT THERMAL PROBE TECHNIQUE FOR
MEASUREMENT OF THERMAL PROPERTIES OF BUFFER SAMPLES



SPEAKING NOTES FOR
A.G. GUSTAFSSON
ATLAS COPCO ENERGY AB
S-105 23
STOCKHOLM, SWEDEN

DRILLING FOR HEAT
THE PRACTICAL ASPECTS

AIRPORT HOLIDAY INN
970 DIXON ROAD
FIESTA BALLROOM

JANUARY 10, 1985
8:30 A.M.

Mr. A.G. Gustafsson

Anders Gustafsson is a representative of Atlas Copco Energy A.B. of Stockholm, Sweden. His presentation will outline heat pump applications in that country.

LOW COST HEATING WITH ATLAS COPCO HEAT PUMP SYSTEMS

The situation in Sweden

There are approximately 50-60,000 heat pumps installed in Sweden. The annual number of installations has been strongly increasing each year. In 1984, 14,000 heat pumps larger than 2 kW were installed.

From the beginning most of these installations were made in single family houses, but today you will find the most profitable installations in apartment houses, schools, churches, industries, etc.

Most of the old installations collect their "free energy" from lakes or soil by long hose lines on the bottom of the lakes or laid down 0.8-1.0 metres in the ground.

Today out-door air and energy wells are the most common sources of energy. Last year, 50 per cent of all wells drilled in Sweden were for energy purposes.

One of the reasons for this development is that the Government since the oil crises have been subsidizing heat pump installations.

At first this was done by "energy loans" without or with reduced interest rate and later with subsidies up to 15 per cent of the installation costs and this goes for both single family and apartment houses.

Other reasons are:

- our good resources of electrical power
- the rather low prices of electrical energy
- a suitable climate
- heating systems with hotwater radiators

There is always a source of "free energy" available.

- Bedrock
- Ground water
- Soil
- Outdoor air
- Ventilation air
- Water from sea or lakes
- Sewerage

are examples of energy sources suitable to be utilized in a heat pump system.

For large district heating systems with heat pumps in the range of many megawatts, the waste energy from the sewerage is the most suitable. One example is Rya Works near Gothenburg which will in 1985 produce 135 MW. To these heat pumps Atlas Copco has delivered large turbocompressors.

However for houses which require from approximately 10 to 400-500 kW, groundwater or bedrock systems are the most suitable. For small villas and houses in areas with mild winters, the outdoor systems are good alternatives.

Energy wells

There are two alternatives

- Ground Water
- Bedrock

The GROUND WATER system requires a very good availability of water and a possibility to get rid of some of the water (for example in a stream, lake or sewerage), as the ground normally does not swallow as much water as can be pumped out of it.

According to Swedish conditions, the wells are drilled down to 150-200 metres with a diameter of 6 1/2 inches. The water is pumped up to the heat pump by a submersible pump and returned into an infiltration well. There are also systems where the water partly returns into the well and partly drains into, for example, the sewerage.

The temperature of the water drawn into the heat pump will be +5°C - +10°C.

The BEDROCK system is the one that is becoming more and more common. The reason is that this is a very simple system which does not require a large amount of water, and for which smaller holes can be drilled; for economical reasons the overburden should not to be thicker than approximately 20 metres.

During the winter the brinetemperatur will be down to -2°C - -4°C.

ATLAS COPCO ENERGY PRODUCT RANGE

The product range of ATLAS COPCO ENERGY contains heat pumps and accessories for water/water heat pump systems from 8 to 700 kW.

There are 4 sizes of Atlas Copco water/water heat pumps. They can easily be combined for higher heat output if requested. The heat pumps are simple to install and can, for example, be brought into the boiler room through a standard door.

The heat pumps have patent high effect evaporators and integrated stainless water heaters containing 138 litres (12 and 16 kw) or 270 litres (24 and 32 kw).

Atlas Copco also has a wide range of water/water heat pumps when more than 100 kw is needed. There are 11 different sizes in the range between 100 and 700 kw.

ATLAS COPCO AIR/WATER HEAT PUMPS

These cover energy requirements between 4 and 120 kw. There are 5 sizes and the largest heat pumps can easily be combined to reach 120 kw.

All models are silenced and have automatic de-icing which makes operation possible down to -10°C - -15°C.

For drilling the energy wells, ATLAS COPCO has a range of suitable drilling rigs:

- AQUA DRILL LWD 200

A trailer-mounted water well drilling rig for the down-the-hole hammer method. Suitable for 4-5 inch borehole down to 120 metres.

- AWUA DRILL R-50

A truck-mounted water well drilling rig for light rotary and hammer drilling methods. Most suitable for 4 - 8 1/2 inch boreholes down to 250 metres.

This was some information about the heat pump situation in Sweden and ATLAS COPCO product systems for heat pumps and energy wells.

SPEAKING NOTES FOR
F.J. LENARDUZZI/D.J. YOUNG
UTILIZATION ENGINEERS
ONTARIO HYDRO RESEARCH DIVISION
TORONTO, ONTARIO

GROUND SOURCE HEAT PUMPS
FOR
SPACE HEATING

AIRPORT HOLIDAY INN
970 DIXON ROAD
FIESTA BALLROOM

JANUARY 10, 1985
2:00 P.M.

D.J. Young

Dave Young graduated from the University of Toronto. He was project co-ordinator for a joint Canadian Electrical Association/Ontario Hydro project, to design and construct northern climate heat pumps. He is Utilization Engineer at the W.P. Dobson Research Laboratory in Etobicoke.

F.J. Lenarduzzi

Frank Lenarduzzi is a professional engineer with Ontario Hydro's Research Facility in the Utilization Section. His duties include assessment of end-use technologies and work with electric storage heating, solar assisted heat pumps and ground coupled heat pumps.

ABSTRACT

Given our Canadian climate, ground source heat pumps provide customers with the lowest operating cost of any commercially available heating system. For an electrical utility, they offer an improved winter load factor (compared to all-electric air-source heat pumps) at less than half the peak electrical demand of an electrical resistance heating system.

Monitoring results of several ground source heat pumps by Ontario Hydro has shown energy savings between 50 and 65 per cent compared to resistance heating. These results are based on evaluations of several closed and open loop residential systems and one commercial closed loop system.

INTRODUCTION

Ground source heat pumps offer a means of raising the natural energy stored in the ground to a useful temperature for space heating, water heating or other heating purposes. Unlike air-to-air heat pumps which undergo dramatic changes in efficiency and output capacity as the outdoor temperature changes, ground source heat pumps have the relatively constant temperature of the soil or ground water as a heat source. This not only makes the overall efficiency higher but could potentially make the equipment more reliable since defrosting and low temperature operations are avoided.

This kind of ground coupled heat pump is not new. Thirty years ago, Ontario Hydro tested a system that used buried copper pipes for ground-coupling. (1) Unfortunately for the technology then, there existed much cheaper heating options. What makes this heating method attractive today are the higher costs of energy, improved trenching and drilling equipment, and advances in the production of low cost plastic pipe.

Recognizing the potential operating cost benefits of ground source heat pumps, a project was undertaken to monitor residential and commercial applications of closed and open-loop ground source system. (2, 3, 4)

QUANTITATIVE MONITORING AND INSTRUMENTATION

The reports referenced above contain details of the monitoring systems employed in each location studied. Typically, we recorded the necessary temperatures and liquid flows on the system to calculate the energy delivered by the heat pump. Electric recording meters were used to determine the energy input to the heat pump. The ratio of these two quantities yields operating efficiency.

An example of the specific monitoring employed at one site is diagrammed in Figure 1, and Table 1.

RESIDENTIAL OPEN LOOP SYSTEMS

When well water is used as a heat pump's heat source, the system is referred to as an open loop ground coupled system. Heat taken from the well water is absorbed by the heat pump's refrigerant which is then compressed to yield a higher temperature for space heating. For the water source heat pump to operate satisfactorily a constant water supply of more than 20 L/min (5 gal/min) is required. The well water often is returned to the water table through a second well or discharged to a surface water-course.

FIGURE 1

FUNCTIONAL SCHEMATIC OF THE GROUND-COUPLED SPACE AND WATER HEATING SYSTEM

(LETTERS REFER TO MEASUREMENT LOCATIONS - SEE TABLE 1)

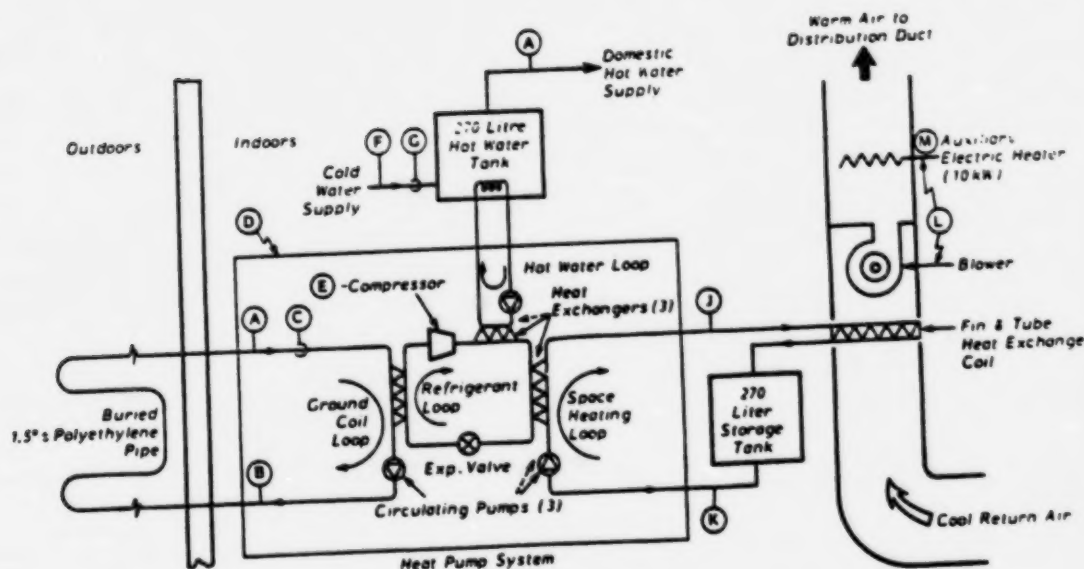


FIGURE 1

FUNCTIONAL SCHEMATIC OF THE GROUND-COUPLED SPACE AND WATER HEATING SYSTEM
(LETTERS REFER TO MEASUREMENT LOCATIONS - SEE TABLE 1)

TABLE 1 - INSTRUMENTATION

Item	Quantity Measured	Instrument	Measurement Point Location (Fig. 2)	Recording Frequency
1.	Brine Inlet Temp.	Electronic Probe	A	Monthly
2.	Brine Outlet Temp.	Electronic Probe	B	Monthly
3.	Brine Flow	Integrating Liquid Flow Meter With Pulse Head	C	Monthly
4.	Energy Absorbed from Ground Coil	Integrating Heat Flow Meter	A,B,C	15-minute (tape)
5.	Electric Energy to Heat Pump Compressor, Pumps, and Controls	Integrating Watthour Meter with Pulse Head	D	15-minute (tape)
6.	Heat Pump Compressor On-Time	Electric Elapsed	E	Monthly
7.	Domestic Cold Water Supply Temperature	Thermocouple	F	Monthly
8.	Water Flow Through Hot Water Heater	Integrating Water Flow Meter	G	Monthly
9.	Domestic Hot Water Delivery Temperature	Thermometer	H	Monthly
10.	Hydronic Heating Supply Water Temp.	Thermocouple	J	Monthly
11.	Hydronic Heating Return Water Temp.	Thermocouple	K	Monthly
12.	Blower plus Auxiliary Heater Energy	Integrating Watthour Meter with Pulse Head	L	15-minute (tape)
13.	Auxiliary Electric Heater On-Time	Electric Elapsed-Time Timer	M	Monthly
14.	Total Household Electric Consumption	Integrating Watthour Meter	-	Monthly
15.	Far Field Ground Temperatures	9 Thermocouples	see Fig. 1	Monthly
16.	Soil Thermal Properties	Electronic Analyzer and 3 Probes	see Fig. 1	Quarterly

Monitoring results for open loop systems show savings between 50 and 60 per cent compared to electric resistance heat. The potential for even greater savings exist if the pumping energy is reduced through good pumping system design.

Pumping energy was found to vary between 20 and 40 per cent of the heat pump's electrical load. All monitored systems had similar well pumps, which also pressurized the domestic water system. This is unfortunate because the water flowing through the heat pump need not be pressurized. In fact, the continuous flow of water through an imposed pressure drop (needed to maintain the domestic supply pressure) can consume a large fraction of the savings you were expecting to get from the heat pump.

Pumping Energy

Pumping power was typically 1,300 watts for the monitored systems even though the units varied in thermal output from 6 to 15 kW. This 1,300 watts may not seem like a large load, however the well pump is 'ON' for long periods (80 per cent of the time during the coldest winter months). For the smaller sized heat pumps, this pumping energy can drop savings 10 to 20 percentage points.

Since this work was carried out, the pumping energy problem has been recognized by pump manufacturers. They stress the importance of pump selection and using large diameter pipe up from the well pump to keep the flow restrictions to a minimum.

To show how pumping power could be reduced, two novel configurations are illustrated in Figures 2 and 3, and others are possible. Figure 2 shows a method to provide low pressure water to the heat pump and higher pressure water to the house from the same well. Two pumps are shown, one to fill a low pressure tank for the heat pump and the second to take water from low pressure and supply the home with water at higher pressure. (Remember that it's important to use large diameter pipe up from the well pump to keep flow restrictions to a minimum!)

FIGURE 2

TWO PUMPS (1 KICKER PUMP) and BATCH TANK

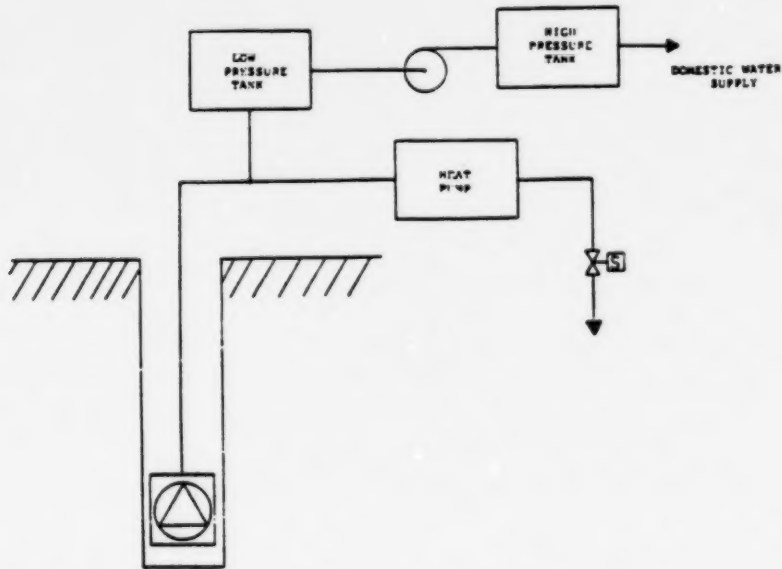
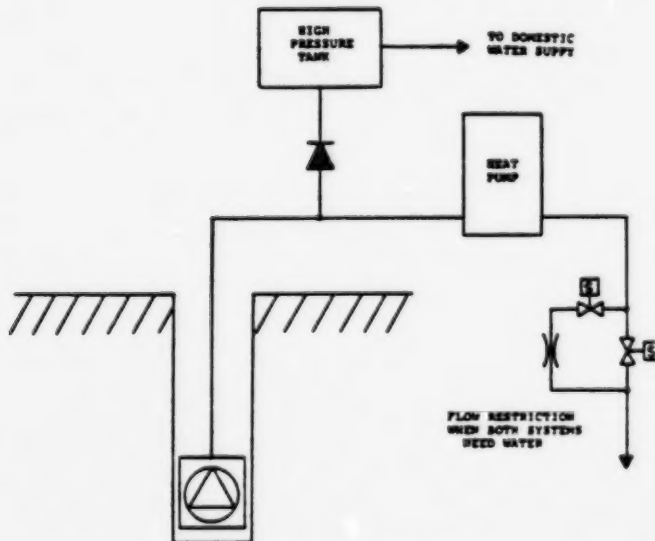


FIGURE 3

TWO SPEED SUBMERSIBLE PUMP



It might be possible in the future for pump manufacturers to develop a two speed submersible pump that would have a low power, low heat mode for the heat pump and a high power mode when the pressure system calls for water (see Figure 3). A simple check valve keeps the two pressure systems separate. If both systems need water at the same time, the low pressure system would operate at the higher pressure necessitating a simple flow restriction, as shown by the two discharge lines in Figure 3.

It should be restated that in spite of the pumping penalties open loop residential systems still showed energy savings as high as 60 per cent for the larger heat pumps (greater than 12 kW).

RESIDENTIAL CLOSED LOOP SYSTEMS

The essential part of a closed loop ground coupled heat pump is the buried plastic pipe. An anti-freeze solution circulates through this pipe, is delivered to the heat pump's refrigerant which is compressed, yielding a temperature high enough for space heating. The pipe can be buried either horizontally, a metre or so below the surface, or inserted vertically into holes normally greater than 20 metres deep.

The most attractive advantage of the closed loop system is the applicability of this heat pump in urban areas where the market potential is greatest. For urban areas the ground coil normally has to take on a vertical configuration, but the performance figures are similar for both horizontal and vertical systems if the systems are properly designed.

The closed loop system has the advantage of using less pumping energy; however, it operates at lower heat source temperatures. For most of Ontario, well water is normally between 5 and 12 degrees celsius. For a ground-coupled system with buried plastic pipes the anti-freeze solution circulating in the pipes can be between -5°C and +5°C. Our monitoring work indicates this anti-freeze solution is normally entering the heat pump between 0 and -1°C for the most of the winter.

Horizontal Closed Loop System

A home located approximately 20 km north of Toronto with a non-reversible closed loop ground-coupled heat pump employing a horizontal buried coil was monitored over one complete year. The heat pump was installed by a qualified dealer. The outdoor ground coil was formed from 430 meters (1,400 ft) of nominal 1.5 inch (3.8 cm) inside diameter polyethylene pipe buried about 1 meter below the surface of the ground. (3)

The schematic (see Figure 1) of the heating system shows the heat pump produces hot water which must provide forced air heating by circulating the hot water to a water-to-air fan coil unit. Since this work was carried out, a newer model has been introduced to provide forced air space heating and cooling directly. Tests in the lab of the newer unit indicate this equipment can achieve a seasonal energy savings of 65 per cent with a ground coil similar to the one described above.

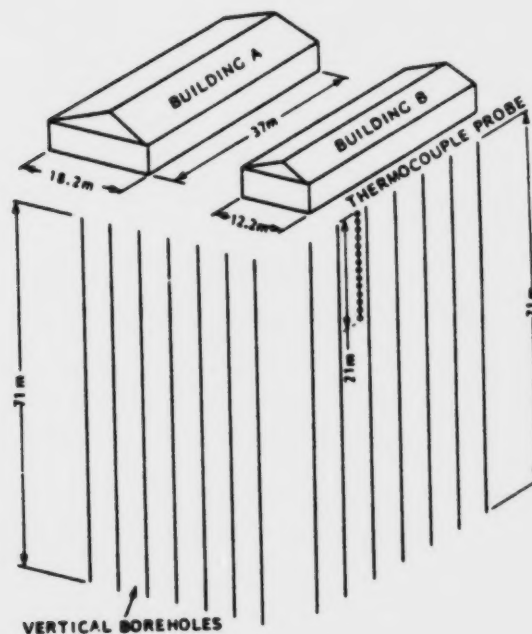
In addition to space heating, this heat pump supplies the domestic hot water needs with a desuperheater large enough to run as the principal condenser. This allows water heating to be provided independent of the heating or cooling mode thus the operating hours and savings of the heat pump are increased.

COMMERCIAL CLOSED LOOP SYSTEMS

To evaluate the actual operating performance of commercial ground source heating systems, two non-reversible closed-loop heat pumps were monitored for a two year period. These heat pumps replaced oil-fired boilers that provide space heating for two Toronto buildings totalling 1,300 m², used principally as machine shop factory space (see Figure 5 for site layout).

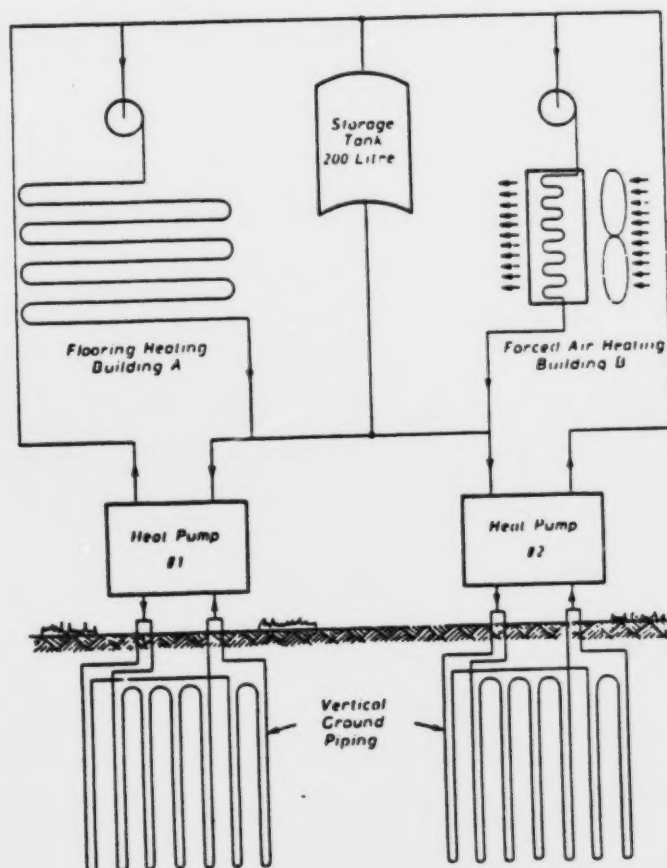
FIGURE 5

COMMERCIAL HEATING SYSTEM GROUND COIL LAYOUT



The system used polyethylene plastic pipe inserted into fourteen holes, 70 meters deep to extract heat from the ground. Each heat pump has 1,000 meters of buried pipe connected to it. Both units produce hot water to provide the space heating requirements of the buildings. In one building, cast iron pipes buried in the floor provide slab heating. In the other, a water-to-air fan coil unit delivers force-air heating in winter and passive air-conditioning by circulating the cool fluid temperatures of the ground coil piping in summer (see Figure 6 for heating schematic).

FIGURE 6
HEATING SYSTEM SCHEMATIC



Winter Performance

During the first winter, the heat pumps consumed 72,500 kWh between November 18, 1982 and June 2, 1983. A seasonal coefficient of performance (SCOP) of 2.5 ± 0.2 was estimated from discrete measurements, the heat pumps saved over 60 per cent of the electrical energy that an equivalent electric resistance furnace would have consumed.

During the second heating season continuously integrated measurements of performance were made with Ontario Hydro-built heat flow instruments. One of the two heat pumps was out of service for a short period of this time because of a blocked heat exchanger. In spite of this, our instrumentation allowed us to estimate the normal overall SCOP of the two systems as 2.6 ± 0.1 .

The total electrical consumption of the heat pumps was 74,500 kWh between October 20, 1983 and June 4, 1984. In addition to this consumption a small amount of back-up heating was used by the oil-fired boiler (less than 400 litres) during days of very cold weather. This auxiliary heating coincided with the condenser problem and unusually cold weather. More favourable weather and circumstances may have completely eliminated the need for back-up as was the case the previous winter.

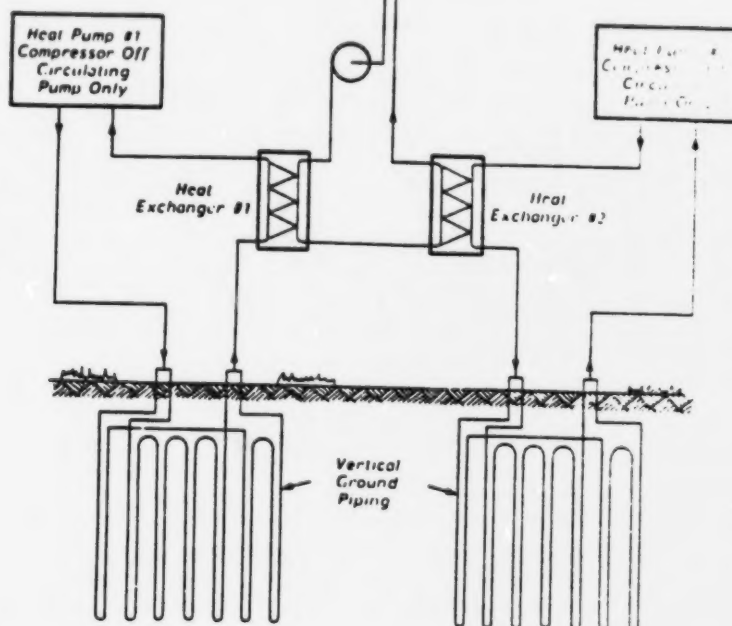
Summer Performance

These heat pumps do not have a reversing cycle to provide air-conditioning, but the cool ground temperatures are used to provide passive cooling in building B. A schematic of the system shows two passive cooling heat exchangers linking the glycol filled ground coil piping with the fan coil unit located in building B (see Figure 7).

Between June 4 and August 27, 1984, 4,470 kWh of electrical energy was used by the glycol circulating pumps to provide the passive cooling. This electrical energy is estimated to provide approximately 1,600 kWh of cooling which is equivalent to a conventional 5 ton air-conditioner operating for 1,000 hours.

Based on the observed operating conditions, the equivalent amount of cooling could be provided if the ground coil circulating pumps operated fewer hours. To determine the minimum operating hours for these pumps to provide adequate cooling and ground temperature recovery requires additional study and trial testing. However, some optimization could provide even greater savings in the cooling mode.

FIGURE 7
COOLING SYSTEM SCHEMATIC



GROUND COIL THERMAL PERFORMANCE

Both the vertical commercial and horizontal residential systems used 1.5 inch polyethylene plastic pipe and operated at similar anti-freeze temperatures. A comparison of the performance figures, however, reveals that the vertical system collects more heat per unit length of pipe.

Table 1 characterizes the thermal and heat transfer performance of the buried plastic pipes. The first column of heat absorption figures refers to the energy absorbed during the actual on time of the heat pumps. The average monthly heat withdrawal rate refers to the heat collected over the whole month. The maximum average monthly heat withdrawal rate was 14.5 W/m for the commercial system. During this period the heat pumps ran for 85 per cent of the time, making the instantaneous heat withdrawal rate 16.5 W/m.

At the residential site with the horizontal configuration of similar plastic pipe buried approximately 1 m deep, the measured maximum monthly average heat withdrawal rate was 10.9 W/m. The corresponding instantaneous heat withdrawal rate was 13.5 W/m.

TABLE 2
THERMAL PERFORMANCE OF BURIED PLASTIC PIPE

	<u>Max. Monthly Average</u> <u>Heat Withdrawal Rate</u>	<u>Instantaneous Heat</u> <u>Withdrawal Rate</u>
Vertical		
Plastic Pipe	14.5 watts/m	16.5 watts/m
Horizontal		
Plastic Pipe	10.9 watts/m	13.5 watts/m

For the horizontal site, the ground coil fluid temperatures were slightly lower than those of the vertical coil (by about 1°C). This is partially because of far field (undisturbed soil) configuration. This, coupled with the fact that the vertical ground coil is in contact with the water table, explains the higher thermal performance of the vertical array. The improved performance with vertical piping is evidenced by trade practice that allows 20 to 30 per cent less pipe for a vertical as opposed to a horizontal ground coil layout, given the same heating load. This reduction is possible in spite of the fact that pipe in a vertical installation is in contact with itself in each bore hole.

SUMMARY

Our field results on open loop well water systems showed energy savings between 50 and 60 per cent. Improved pumping design could increase savings. The results are somewhat lower than expected.

In 1985 we plan to test newer units on the market and continue to investigate pumping systems improvements.

Our field tests on closed loop systems indicate energy savings between 55 and 62 per cent. A laboratory evaluation of other heat pump models indicates energy savings of as high as 65 per cent are possible.

Regardless of the heat source well water or buried plastic pipe, ground source heat pumps have demonstrated the lowest operating cost of any heating system. The two main benefits are energy savings of up to 65 per cent for the customer and a 50 per cent electrical demand reduction for the utility compared to electric resistance heating.

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3. Young, D.J., Lenarduzzi, F.J., "Measured Performance of a Dealer-Installed Residential Ground-Source Heat Pump System", National Research Council Final Report for Contract No. 05X82-00083.
4. Svec, O.J., Goodrich, L.E., and Palmer, J.H.L., "Heat Transfer Characteristics of In-Ground Heat Exchangers", National Research Council, Division of Building Research, Paper No. 1136 (Reprinted from Energy Research, Vol. 7, 1983), Ottawa, 1983.

SPEAKING NOTES FOR
HELMUT SPIESER, P.ENG.
ONTARIO MINISTRY OF AGRICULTURE AND FOOD
RIDGETOWN COLLEGE OF AGRICULTURE TECHNOLOGY
RIDGETOWN, ONTARIO NOP 2C0

OPPORTUNITIES FOR
WATER SOURCE HEAT PUMPS
IN AGRICULTURE

AIRPORT HOLIDAY INN
970 DIXON ROAD
FIESTA BALLROOM

JANUARY 10, 1985
2:00 P.M.

H. Spieser

Helmut Spieser graduated from the University of Guelph, with a B.Sc. in Engineering. His work includes testing and development in energy conservation areas, and in techniques, testing, and demonstrations on farms for the Ontario Ministry of Agriculture and Food. Greenhouse heating with heat pumps is of special interest.

ABSTRACT

In an effort to evaluate the economics of alternate heating systems for greenhouse heating, a project was set up to monitor the performance and economics of a heat pump system in a greenhouse. Three water source heat pumps were used to successfully heat an air-inflated, double polyethylene covered greenhouse during the '82-'83 and '83-'84 heating seasons. Water from a well was used by the heat pumps to heat the greenhouse. Cooled discharge water was reinjected back into the same aquifer a short distance away. Cost for heating with the heat pumps was roughly 30-35 per cent less than heating with steam produced by natural gas.

As well, two projects have just been initiated which will evaluate the feasibility of: cooling a new mushroom plant, and artificially controlling soil temperatures in a greenhouse to grow specialty flowers with water to water heat pumps.

GREENHOUSES

Greenhouses use large quantities of energy to maintain proper temperatures for the crop being grown. Water to air heat pumps have been used for the past three years to heat one bay of multi-bay, doubly poly, air-inflated greenhouse range growing tomatoes.

Three 12 ton water to air heat pumps are being used to heat one bay which is 640 m² of this greenhouse range. These heat pumps have twin compressors, with the second compressor starting after a 3-minute time delay after the first compressor. As well, the heat pumps have twin condensers and twin evaporators. The thermostats for the heat pumps are set roughly 1°C apart so that the units will switch on one at a time as the temperature falls in the greenhouse.

Water for all three heat pumps is supplied from a common supply well which is 14 m deep. A header then carries the water to each unit. The water temperature in the well has remained at a near constant 16°C. Each unit uses 2 litres of water per second when it is operating. To save on pumping costs and conserve water, solenoid valves on the individual heat pump water supply lines close when the units are not operating. The water is cooled by a maximum of 4°C by the heat pumps, which in turn raise the greenhouse air temperature from 20°C to 31°C.

The cooled water is collected in a common header and discharged into a return well, 14 m deep situated 46 m away from the supply well. This separation distance was necessary to eliminate any possibility of thermal breakdown of the supply well.

A kilowatt hour meter was used to measure the electrical power consumptions of the water supply pump and the three heat pumps. Steam consumption of an identical, adjacent greenhouse was accomplished by measuring the volume and temperature of the steam condensate from that greenhouse.

Results showed that the heating costs from the heat pump heated greenhouse were between 30-35 per cent less than the heating costs from the steam heated greenhouse. The seasonal COP of the heat pump system was 2.76. This heating system has been functionary for the past three years with few problems. One control unit malfunctioned, was replaced and has not caused any further problems.

One thing which must be noted is that cooled water return lines must be situated such that they are not directly over a crop row since moisture from the air will condense on the pipe and drip. Water dripping onto plants could cause problems with blemishes on the crop being grown. The total cost for this system which includes the two wells, water supply well, three heat pumps, piping, and installation was roughly \$50,000. This heating system worked very well but the economics and payback of this type of system will dictate if it becomes widely accepted by the greenhouse growers.

MUSHROOM PLANT

In the overall yearly picture, the cooling load for a mushroom plant is greater than the heating load. This is due in part to the fact that heat is produced as the compost breaks down. Water source heat pumps connected to a buried ground loop serve to provide total cooling as well as heating for a new mushroom growing plant. Since high temperatures are required for compost cookout, which are not possible with the heat pumps, steam from a boiler is still required. This mushroom plant has a floor area of 2220 m². For the heating mode, three water to water heat pumps, each with an output capacity of 5 tons, are used to extract heat from a buried ground loop. This loop consists of 2400 mm of 38 mm diameter polyethylene pipe buried 2300 mm deep in a field adjacent to this mushroom plant. Cost for the polyethylene pipe and trenching is roughly \$3.25 per metre of length. In the cooling mode these same three heat

pumps are used to extract heat from the mushroom plant and dissipate it through the ground loop. As well two additional 5 ton water source heat pumps dissipate heat into a small pond situated some 300 m from the mushroom plant.

These heat pumps are staged to provide better control and reduce energy wastage from overloading or underloading. Heat is transferred to or removed from the mushroom growing rooms by means of a heat transfer loop from the heat pumps and a heat exchanger in each room.

Monitoring on this project is just being started. It would appear from the preliminary results that heating with heat pumps is roughly 50 per cent less costly than heating with steam from a natural gas fired boiler.

SOIL COOLING

Certain plants, such as Freesia, require very close control of soil temperature in order for the bulbs to grow properly and produce flowers. Without soil cooling one has to use the natural seasonal soil temperature fluctuations and plant accordingly to hit the optimum soil temperature. Water to water heat pumps are being used to provide artificial soil cooling in one greenhouse. This is a two well system where water is extracted from one well, passes through the heat pumps and is reinjected back into the ground through a recharge well. Three 5 ton water to water heat pumps are used to cool the soil in a greenhouse with an area of 1020 m².

During warm weather, chilled water in the heat transfer loop from the heat pumps is circulated through buried loops in the flower beds. During the winter months when the soil is warmed to the desired level, excess heat production from the heat pumps is diverted into unit heaters which assist in heating the air in the greenhouse. Monitoring of this project will be carried out for the '84-'85 heating season.

The systems described are merely a few of the possible applications of water source heat pumps in agriculture. Other areas where heat pumps may be used include: livestock barns, controlled atmosphere storage, cold storage facilities, fishing boats, or grain drying. In short, any area of agriculture requiring heating and/or cooling.

FURTHER INFORMATION

Spieser, H. 1983 - Feasibility of Water to Air Heat Pumps for Greenhouse Heating CSAE Paper No. 83-506, presented at Truro N.S., June.

SPEAKING NOTES FOR
DAVID L. HATHERTON
FOUNDER-CHAIRMAN & C.E.O. EARTH SYSTEMS LIMITED
LEAMINGTON, ONTARIO
DIRECTOR & CO-FOUNDER WATERFURNACE INTERNATIONAL INC.
FORT WAYNE, INDIANA

EARTH COUPLED HEATING
AND COOLING SYSTEMS
COMMERCIAL APPLICATIONS

AIRPORT HOLIDAY INN
970 DIXON ROAD
FIESTA BALLROOM

JANUARY 10, 1985
2:00 P.M.

D.L. Hatherton

David Hatherton is Chairman of the Board and Chief Executive Officer of Earth Systems Ltd. of Leamington. He is co-founder and Vice President of marketing for Waterfurnace International, of Fort Wayne, Indiana, and has been involved with earth coupled heat pump systems over 5 years, with over 5,000 installations.

Energy conservation in commercial buildings is becoming a major concern for developers and building owners. This element in the operating costs of real estate is in many ways beyond their control. The owners can upgrade the structure only to a point and then the heating and cooling systems must be replaced with more efficient equipment. In many instances the owners are looking for "state of the art" systems and with enough research the earth-coupled concept becomes increasingly attractive. On new structures the earth coupled systems can be a very cost effective capital expenditure showing a positive return on investment. The system only has to show a return on the difference in cost between itself and the alternative and this can be done with energy savings and life cycle cost.

Architects have shown a great deal of interest in commercial and residential application of the earth coupled systems. Much of their interest comes from the concerns they have about aesthetics of the projects. The systems do not need to have noisy and somewhat unsightly air handling units outside.

These factors are of a great deal of importance and makes their job easier, in that they do not need to design around the air handlers. The units are single packaged, don't require chimneys, or any outdoor equipment.

The major problem with the application of earth coupled systems to commercial buildings is that there are very few engineers available with the practical knowledge of how to design the system. In spite of this a significant amount of the systems are in and operating as they were designed. There are a number of commercial installations in Ontario with over 30 tons of equipment in operation. In structures from fast food restaurants to old age homes to green houses and motels.

Commercial applications have not been a market that has been pursued. It is apparent though, that with the amount of interested parties contacting us to engineer the system, the commercial field is expanding on its own merits. I feel that there is a need for extensive education of engineers, architects and mechanical contractors to ensure that the system is properly applied. This seminar is a first step in showing the potential of the concept. The interest of many people has been aroused, now the proper education must begin.

I have been involved with this concept for over 5 years and have seen over 5,000 of our systems installed in Canada and the U.S. The applications have been from 1 to 450 tons with earth loop piping over 20 miles in length, in vertical and horizontal configurations. Earth-coupled units are in operation in the north, including Timmins, Ontario, Northern Quebec, and British Columbia. In the south from southern Florida, Louisiana, Arizona and Las Vegas, Nevada. The largest concentration being

in Essex and Kent counties in Ontario with over 350 systems in operation, some for over 4 years. This is a system that can, without question, provide heating and cooling energy at a fraction of the cost of anything on the market and at a reasonable cost.

The Department of Energy in Washington has seen fit to award one of the residential customers the award for Energy Innovation.

Please find attached a detailed list of Commercial Applications.

COMMERCIAL
INSTALLATIONS
SURVEY

COMMERCIAL SYSTEM CASE STUDY

Project: St. Charles Hospital
New Doctors Building
Toledo, Ohio

Notes: Office condominiums for doctors.
Total conditioned area 8,500 sq. ft. at present.
New construction, operational October 1983.
Well insulated structure, conditioned year round.

System: Each suite has WaterFurnace units on vertical earth loops.
2-SWPHXR351 in commons on individual loops and LPK411
6-SWPHXR091 2-SWPHXR211 4-SWPHXR281 for suites.
Each suite has 2 units on one loop system and one LPK411.
8 separate loops of 3-100' deep 1.5" series u-bend bores.
Total bore 2,400' - Total tons 24.5 (load much less).

Alternative: (1) VAV units with hot and chilled water from hospital sys.
(2) Water source heat pumps on boiler/tower loop system.
There were 7 systems considered totally.

Costs: Estimated \$20,600 more than VAV system: \$840/ton more.
Estimated \$17,000 more than boiler/tower: \$649/ton more.

Comments: Alternates were dismissed due to central system operation
preventing the individual metering that was desired.
Operating costs, maintenance, and appearance were factors.
Loop temperatures in the low 30's have been observed.
System installed by standard mechanical contractor (by bid).

DOCTORS' BUILDING
ST. CHARLES HOSPITAL
HVAC SYSTEM - VALUE ENGINEERING ANALYSIS

SYSTEM	EQUIPMENT LIFE	ENERGY COST**	FLEXIBILITY	APPEARANCE	METERING	INSTALLATION COST \$ MECH. \$ ELEC.	REMARKS
1. Heat Pump - Ground Water Loop 2 Units per Suite - All Electric Air Heating and Cooling	8-12 Years	-10%	Very Good	Excellent	Separate	+10,600 +10,000	Best appearance and affects the construction of the building the least. Good zoning.
2. Variable Air Volume - High Temperature Hot Water and Chilled Water from Newell Hot Water Radiation	35 Years	0%	Excellent	Excellent	Central	0 0	Best life cycle cost of systems.
3. Variable Air Volume - Air Cooled Condenser and Gas Boiler and Hot Water Radiation	25 Years	+8%	Excellent	Good	Central	+1,200 +1,500	Good life cycle cost of system.
4. Heat Pump - Water to Air Closed Loop - with Cooling Tower and Gas Boiler 2 Units per Suite All Air System	8-12 Years	+12%	Very Good	Good	Mostly Separate	-6,400 +10,000	Life cycle cost of system is the best of systems with separate metering. Good zoning.
4a. 1 Unit per Suite with Electric Radiation on Exterior Wall	8-12 Years	+18%	Good	Good	Separate	-34,400 +11,150	No zoning of exterior and interior rooms on cooling unless radiation functions as reheat.
5. Air to Air Heat Pump with Electric Radiation - 1 per Suite - All Electric	Blower Unit 12-15 Years Heat Pump 5-8 Years	+45%	Good	Fair	Separate	-42,900 +19,500	No zoning of exterior and interior rooms on cooling unless radiation functions as reheat. Poor energy utilization.
6. Furnace and Heat Pump 1 per Suite - Gas or Electric Heat - Electric Cooling	Furnace 12-15 Years Heat Pump 5-8 Years	+25%	Fair	Fair Chimneys	Separate	-26,700 +7,500	No zoning of exterior and interior rooms. Suite heat loss too small for good furnace application - poor operation.
7. Furnace and Air Cooled Condenser - 1 per Suite Gas Heat - Electric Cooling Electric Entry Heater	Furnace 12-15 Years Heat Pump 5-8 Years	+30%	Fair	Fair Chimneys	Separate	-39,600 +5,000	No zoning of exterior and interior rooms. Suite heat loss too small for furnace application - poor operation. Low installation cost.

* No cooling available below 40 F outside air temperature. Cooling will be needed during occupied period in interior areas year around.

** Interesting point, electricity will cost approximately 2¢ per kW more when metered separately.

COMMERCIAL SYSTEM CASE STUDY

Project: J. Lynmar Manufacturing, Inc.
Masontown, PA

Notes: Manufacturer of coal mining equipment replacement parts.
Machine shop area 30,600 sq. ft. - Office area 6,020 sq. ft.
New construction, operational January 1983.
Well insulated structure, conditioned year round.

System: Multiple WaterFurane units on common vertical earth loop.
10-SWPHXR544 1-SWPHXR354 1-SWPHXR1544: 63 tons.
56 vertical 1.5" u-bend bores 150' deep: 8400' bore.
Total system flow of 200 GPM - Propylene glycol.

Alternative: Office - Rooftop air to air unit with hot water baseboard.
Shop - Coal and gas boilers feeding hot water fan coil units.
Shop - Evaporative (swamp) cooling units.

Costs: Total cost to building owner for complete system: \$128,000.
Includes sheet metal, insulation, drilling, etc: Total cost.
Conventional system cost \$110,000: Difference \$18,000.

Comments: Owner extremely satisfied with system performance.
Installed system to reduce operating and maintenance costs.
Loop temperatures have ranged from 44 to 78 degrees.
No maintenance has been required on the system.
Standard mechanical contractor installed system.

COMMERCIAL SYSTEM CASE STUDY

Project: Chester Herder & Son, Inc.
Three Bridges, NJ

Notes: Insurance agency with subleased office space.
Total conditioned area 6,000 sq. ft.
New construction, operational January 1983.
Well insulated structure, conditioned year round.

System: Multiple WaterFurane units on common horizontal loop.
2-WP351 split system 1-SWPR461: 10 tons.
2 horizontal 2" earth loops 1800' each with 2 pipes 5' deep.
Total flow of 30 GPM - Single pump feeds all units.

Alternative: Air to air heat pumps.

Costs: Total installed cost to building owner: \$20,300.
Includes sheet metal, excavating, etc - complete system.

Comments: Owner very pleased with operating cost and performance.
Installed system for reduced operating and maintenance.
Loop temperatures have ranged from upper 30's to 80's.
No maintenance problems have occurred.

COMMERCIAL SYSTEM CASE STUDY

Project: Hawaii Koi Corporation
Mountainview, Hawaii

Notes: 5 acres of single poly greenhouse.
Operational since November 1983.

System: Multiple WaterFuranc units on recirculation loop to pond.
35-SWPHXR513 units: 140 tons.
Units operate on water from rainwater catch pond and are fed from the irrigation piping system located in the houses.
The solenoid valve controlled units return the water back to the catch pond through a return piping system.

Alternative: Fossil fuel unit heaters.

Costs: Equipment was installed by owners - no cost data available.

Comments: System chosen due to extreme fossil fuel costs on Hawaii.
Pond, pump and supply piping were required for irrigation.
300" rainfall insures supply and proper temperature water.
Crop production has doubled over previous w/o heat.
Return on capital in less than one year due to production increase.

COMMERCIAL SYSTEM CASE STUDY

Project: Corporate Square
Hulman & Company, Inc.
Terre Haute, IN

Notes: School conversion to office building.
Conditioned area approx. 150,000 sq. ft.
Retrofit expected online May 1984.

System: Multiple WaterFurace units on common vertical earth loop.
1st Phase: 129 tons all SWPHXR units from 061 to 351.
2nd Phase: Approx. 250 tons additional summer 1984.
324 vertical 1" u-bend bores 150' deep: 48,600' bore.
27 zone 2" headers each feeding 12 bores in parallel.
Zone headers fed from 10" main headers in u.g. valve pit.
Total system flow (both phases) 1,000 GPM - Methanol.

Alternative: Water source heat pumps on boiler/cooling tower loop.

Costs: Total cost to building owner of complete earth loop system
stubbed into building \$264,000: \$697/ton.
This includes excavation, drilling, pipe, labour, pit, etc.
Estimated \$150,000 more than boiler/tower: \$396/ton.

Comments: System installed because owners like the concept, and the
reduced operating and maintenance costs show 3 year return on
investment.
3 drilling rigs are currently putting in up to 24 bores per day.

COMMERCIAL SYSTEM CASE STUDY

Project: Montgomery Knoll
Princeton, NJ

Notes: Office condominium development.
10 condo's from 1,500 to 1,900 sq. ft. each.
New construction, operational August 1983.

System: Each condo has a WaterFurnace unit on a vertical loop.
19 SWPHXR units ranging from 351 to 541: 66 tons.
Each condo on 1.5" series vertical loop from 300 to 500'.
Each unit has an LPK and 2 zone duct damper system.

Alternative: Gas furnace with electric a/c. Individual room thermostatic
dampers. 2 systems per condo (upper and lower level).

Costs: Complete installed systems cost owner \$9,000 to \$12,000.
Includes \$1,000 per system for concrete pumped in bores.
Alternative system costs \$7,000 to \$10,000 installed complete.
Total cost: \$3,000/ton. Difference cost: \$571/ton.

Comments: Developer installed for quietness, asthetics, operating and
maintenance costs, and the concept. The concrete backfill was
required due to surface contamination of the site. The cost of
this pure cement mix proved considerable as many underground
voids were being filled along with bore. The coordination of
trades and timing of loop installations was difficult with
construction in various stages on the site. Winter 1984
operating cost for heating ran 500 kWh/month.

COMMERCIAL SYSTEM CASE STUDY

Project: Interstates Electric and Engineering Co. Inc.
Sioux Centre, IA

Notes: Mechanical and electrical contractors offices.
Total conditioned area 12,000 sq. ft.
New construction, operational January 1984.

System: Multiple WaterFurance units on common vertical earth loop.
11-SWPHEXR261: 22 tons.
12 vertical 1" u-bend bores 200' deep: 2400' bore.
12 bores in parallel fed from header in underground pit.

Alternative: Water source heat pumps on boiler/cooling tower loop.

Costs: Earth loop system cost \$5.50 per foot of bore installed.
Other costs not available due to owners installing system.

Comments: Owners estimate operating cost since January at \$5/day.
Lowest observed loop temperature has been 40 degrees.
Installed system to reduce operating costs and eliminate the
maintenance and aesthetics of the cooling tower.
The building loads are less than the tonnage would indicate.

COMMERCIAL SYSTEM CASE STUDY

Project: Ramada Inn.
Eureka Springs, AR

Notes: 90 room hotel w/conference center and indoor pool.
New construction, expected online June 1984.

System: Multiple WaterFurnace units on common horizontal loop.
180 tons: SWPHXR units ranging from 091 to 611.
Special 1" horizontal grid exchangers located in and under
2-4000 sq. ft. wastewater sand filter tanks and a 4000 sq. ft.
aeration and evaporation tank. Also a special pool heating and
dehumidification system for the indoor pool area.

Alternative: Multiple boilers and chillers supplying 4 pipe room fan coil
units and 2 pipe fan coil units for common areas. A makeup air
pool room dehumidification and gas pool heating system. Cooling
tower for chiller heat rejection.

Costs: Basic equipment costs nearly equal. Inside piping simpler for
WaterFurnace. Eliminates all controls, etc.
Additional cost for horizontal exchanger is undetermined.

Comments: Owners decision based upon operating and maintenance costs as
well as aesthetics (cooling tower). Also the idea of getting a
return out of the substantial investment in the wastewater
treatment system was extremely appealing.
System is quasi-experimental: additional loop may be added.
Wastewater volume and building loads go up together.

SPEAKING NOTES FOR
U. GINO DIREZZE, P.ENG.
VILLENEUVE LIMITED
TORONTO

THE ECONOMICS
OF
GROUND COUPLED SYSTEMS

AIRPORT HOLIDAY INN
970 DIXON ROAD
FIESTA BALLROOM

JANUARY 10, 1985

2:00 P.M.

U.G. DiRezze

Gino DiRezze is a graduate of the University of Ackron, and the Ryerson Polytechnical Institute, of Toronto. Presently co-owner and Vice President of L. Villeneuve Ltd., he was previously employed by Canadian General Electric as National Service Manager for heating and airconditioning products.

INTRODUCTION

This paper is intended to give the participants an awareness or a feel for the economic viability of the ground and water source heat pump and how it compares to conventional forced air systems.

Necessary assumptions were made to establish a base for generating statistical data and compare theoretical results with our own field experience.

Although conventional systems comprise 90 per cent of the volume sales in our business, the ground source sales in 1984 were 4 times that of 1983, and there are good reasons why we feel that this trend will continue.

FRAMEWORK FOR ECONOMIC EVALUATION

To properly address the topic of economics of the ground and water source heat pumps, it is necessary to list the variables that influence the economics. These variables are: fuel costs, fuel availability, and initial installation costs. Other variables include: efficiencies of all systems studied, climatic conditions, energy requirements of the building, maintenance and life of the equipment, and lastly, the ground soil type or water availability for the appropriate system.

Toronto was the city used as a basis for calculations. When compared to some of Canada's major centres, it has many average variables such as climate, fuel cost, installation costs, fuel availability and inconsistent soil types in the ground.

Two different size homes were used in the study to check the relationship between energy consumption and economics. The two structures selected were: a smaller model home with an approximate area of up to 2,000 square feet (15 kWh-heat loss) named model No. 1, and a larger home with an area of up to 5,000 square feet (40 kWh-heat loss) named model No. 2.

Three basic and common types of water and ground source systems were used to compare with conventional heating and cooling systems. A water source system (Type "W"), a horizontal and lower cost vertical loop (Type "HV"), and thirdly, a higher cost vertical loop (Type "V").

The water source, open loop, system (Type "W") is installed in a home that has an existing (high producing) well and capable of discharging the water (Fig. 1). This system is the lowest of all three types and is primarily used in rural markets where an existing well producing more than 1 1/2 GPM per ton (3.5 kW) is available. It may, however, require more maintenance than the other two if water quality is a problem.

The horizontal or lower cost vertical closed loop system (Type "HV") is the mid range cost of the three systems (Fig. 2). This horizontal installation requires 1/3 of an acre or more lot size. A backhoe or chain trencher is used for trenching which generally requires a minimum of 400 square feet per ton. The lower cost vertical closed loop can be drilled by an inexpensive auger drill rig provided that the soil condition is right. If a clay soil condition exists, inexpensive vertical drilling can occur and will require a minimum of 125 feet per ton, and can be installed in a regular city lot.

The third type and the highest cost installation of the three is also a vertical installation named (Type "V"), (Fig. 3). Unlike the previous vertical closed loop installation, this one requires a more expensive rotary drilling rig due to ground conditions other than clay and auger drilling is not possible. This installation can also be installed in regular city lots.

ECONOMIC EVALUATION

Installation Costs:

The cost of installations of the ground and water source was compared to the conventional systems, namely: the oil furnace, the electric furnace, the standard gas furnace, the high efficiency gas furnace, and the all-electric heat pump (Table 5). Each of the conventional systems included a central air conditioner, while cooling generally comes with the ground or water source. The hot water heater is not part of the installation cost and neither is the ductwork which is common to all 6 systems. This study is generally directed towards the retrofit market rather than the new-home market. The cost of the electrical service is included and it varies from \$1,100 for the 200 A service in the smaller home, to \$2,500 for the 400 A service in the larger home. Oil tanks for oil furnaces, and chimney liners for the standard gas furnaces are not included in the installation costs. Similarly for the water source system (Type "W"), it is assumed that the well is existing. Hot water consumption is assumed at 47 CDN gallons per day for the smaller home and 91 CDN gallons for the larger home at a T of 90°F.

In 27 of 30 possible combinations of installations, the conventional heating systems were less expensive than the ground and/or water source heat pumps. The largest cost difference showed a 213% cost increase between the oil furnace and air conditioner and the higher cost vertical loop in the smaller home (Table 3). This spread is slightly reduced with the larger home. Our experience shows that this trend continues as systems get larger, ie. commercial.

SAVINGS

Calculations show that the first year savings by the ground and water source vary from a low of 41 per cent over a high efficient gas furnace to as high as 71 per cent over an oil furnace system (Tables 1a, 1b, 1c, 2a, 2b, 2c). Since it was assumed that all three types of installations "W", "HV" and "V" gave a seasonal performance of 2.8, this therefore shows the same savings and operating costs.

PAYBACK ANALYSIS

The payback analysis is based on initial installation costs (Table 5), fuel prices (Table 9), and energy consumption (Tables 1a, 1b, 1c, 2a, 2b, 2c). A 10 per cent increase is assumed for all fuel costs for a 10-year period. Maintenance cost and cost of money is not included in the return on investment (R.O.I.) calculations. ASHRAE data shows that the ground and water source life expectancies are similar to that of the fossil fuel furnace.

The highest installation cost spread between a water or ground source and a conventional system is \$6,800 (213%). This was between the oil furnace and the higher cost vertical closed loop (Type "V") installation on the smaller home model No. 1, (Table 1c). For the larger home, model No. 2, a similar installation comparison shows a \$10,200 cost difference. Furthermore, this comparison shows a 10-year savings of \$41,013 after paying the initial installation cost difference.

Paybacks ranging from immediate to 7.2 years are calculated with comparisons on the larger home (model No. 2). The smaller, less energy consuming home, shows the longest payback at 11.3 years, (when the larger cost vertical is compared to the high efficiency gas furnace).

The largest cash savings accumulated over a 10-year period, amounted to \$49,413 when the oil furnace was compared to a water source on a larger home. On the smaller home, the same installation comparisons netted \$10,233 after the installation cost difference was paid.

Only one combination of the 30 comparisons showed a return on investment of 0%, and a cash savings of \$0, with an 11.3 year payback (when the higher cost vertical was compared to the high efficient furnace) in the smaller home. The same comparison in the larger home showed more respectable results of 7.2 years payback, 8 per cent return on investment, and a cash accumulation of \$5,525.

SUMMARY

- The larger home (model No. 2) showed better economic returns for the ground and water source heat pumps than the smaller home (model No. 1).
- The average installation cost spread of the ground and water source is 75 per cent for model No. 2, and 88 per cent spread for model No. 1 over conventional systems (Table 3).
- The payback years, return on investment averages are 2 times better for the larger model (Table 3).
- The accumulated cash flow average is 6 times higher for the larger home (\$25,165) over the smaller home (\$4,533) (Table 3).
- Overall there are better economic incentives for larger, more energy consuming buildings to choose the water or ground source than for the smaller structures.

CONCLUSIONS

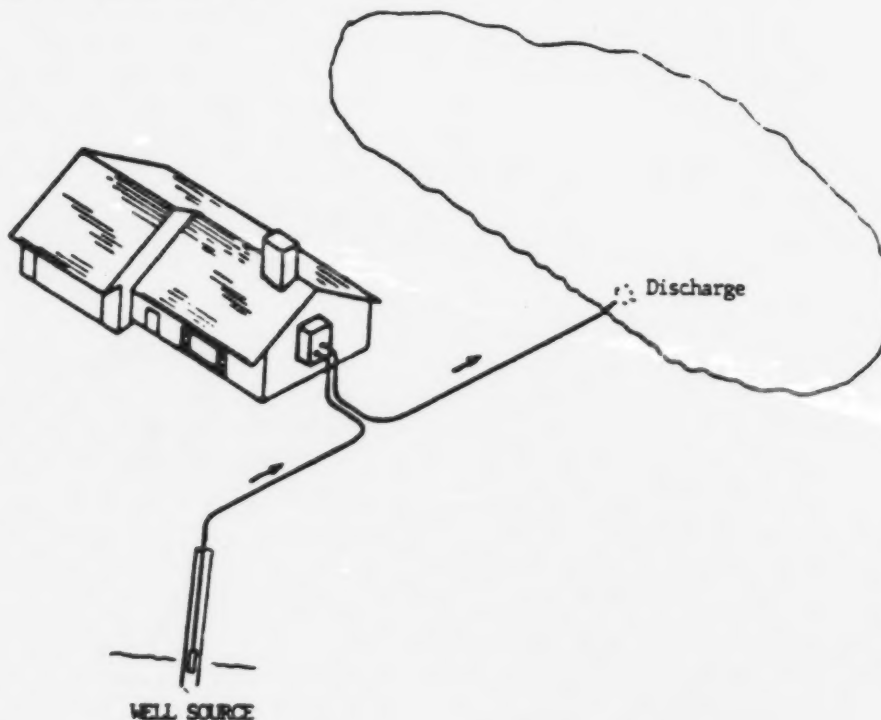
1. Larger, more energy consuming structures have most to gain by purchasing the higher cost, more efficient system. However, 25 per cent of all systems sold by our contracting firm were not economically feasible, but the homeowner felt a certain independence to be able to have his own thermal well.
2. The initial cost of installation may frighten many purchasers away, and may not be aware that paybacks may be less than 3 years.
3. 25 per cent of systems sold by our contracting firm were not economically feasible by "payback standards"; however, homeowners insisted on buying the system, feeling that they were buying a bit of independence by having their own thermal wells.

FIG. 1

INSTALLATION TYPE "W"

WATER WELL SOURCE - OPEN LOOP

This type of installation is primarily for homes or buildings in rural areas where a high producing well (min. 1 1/2 GPM/ton) is available and water is easily discharged. This type of installation is the least expensive of the three, with efficiencies similar to the other two (provided well is not too deep). Maintenance may be a little more than a closed loop if chemical content in the water is high.



COSTS: If Well Is Not Drilled

- Well drilling with casing 5"-6" dia. \$18-\$23/ft.
- Well screen \$600
- Well Pump and Tank (determined by depth of well) \$800-\$1,600

REQUIRE: 1 1/2 GPM per Ton (3.5 kW) capacity

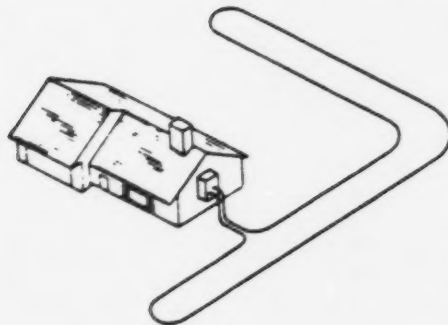
NOTE: A second discharge well is necessary if water discharge is a problem.
 A second well does not require a pump and tank.

FIG. 2

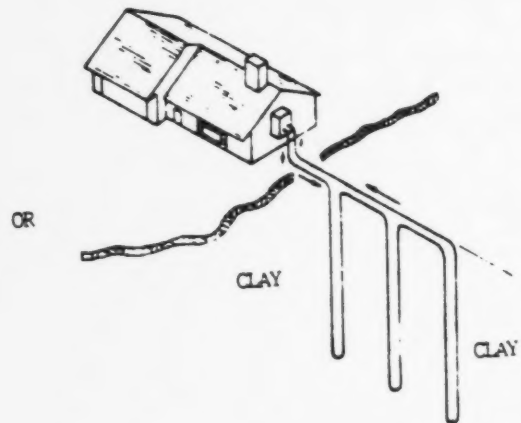
INSTALLATION TYPE "HV"

This type of installation is horizontal closed loop for lots greater than 1/3 of an acre or for regular lots vertical installation where the soil (clay) will allow a small auger drilling machine to bore the holes. This installation type is mid-cost range - more expensive than "W" and less than "V".

HORIZONTAL - CLOSED LOOP



VERTICAL-CLOSED LOOP



- COSTS:
- Horizontal Trenching \$0.70-\$1.00 per foot (chain or backhoe)
Pipe: 1 1/4"-1 1/2" dia. \$0.35-\$0.70 per foot
 - Vertical Auger Drilling min. \$1.00 per foot
Pipe: 1"-1 1/2" dia. \$0.50-\$0.90 per foot (2 pipes per hole)

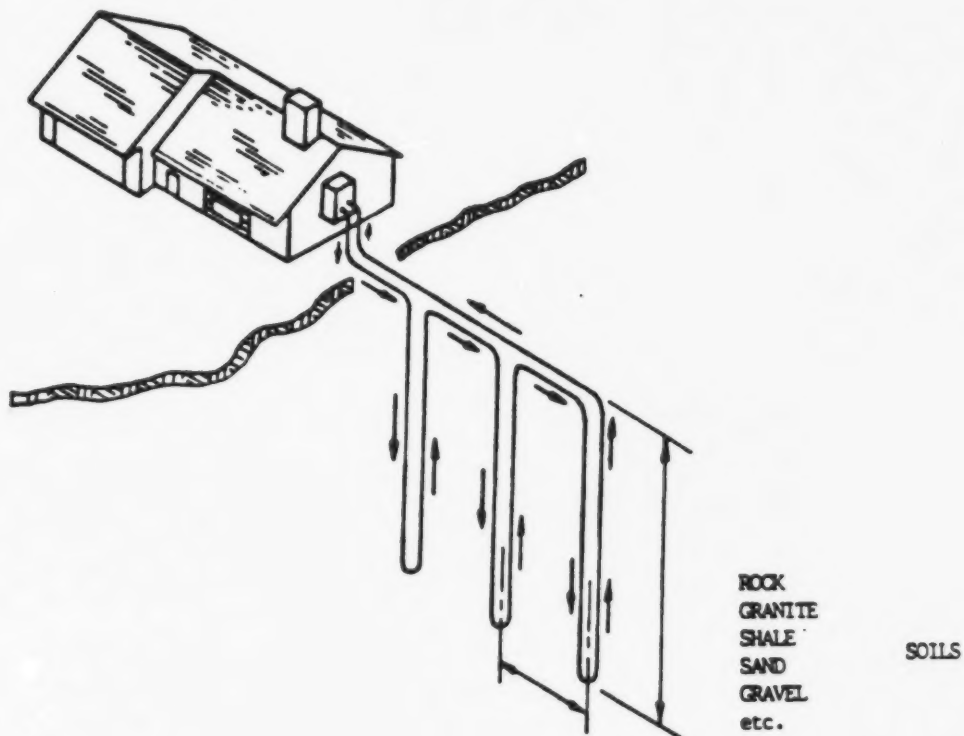
REQUIRE: Minimum 400 ft. per ton (3.5 KW)

CIRCULATION: Closed Loop 36 PM per Ton (3.5 KW)

FIG. 3

INSTALLATION TYPE "V"

This type of installation is the most expensive of the 3 types. It is assumed that the soil type will require an expensive Rotary Rig that will be able to go through any soil condition, and keep the bored hole open. Installation of Type "V" can be done in city lot size homes, or buildings -- the front yard mainly.



COSTS: Drilling \$5.00-\$7.00 per foot
Pipe 1" - 1 1/2" \$0.50-\$0.90 per foot

REQUIRE: Hole depth totals of \$25-\$225 ft. per ton (3.5 kW) (commonly 2 pipes per hole)

CIRCULATION: 3 GPM per Ton (3.5 kW)

VARIOUS HEATING AND COOLING SYSTEMS	ENERGY ANALYSIS		COMPARED TO WATER SOURCE HEAT PUMPS				PAYBACK ANALYSIS		
	ENERGY CONSUMED	FIRST YEAR ENERGY COSTS (\$)	FIRST YEAR SAVINGS OVER CONVENTIONAL (\$)	INSTALLATION COSTS		YEARS TO PAY BACK THE DIFFERENCE	RETURN ON INVESTMENT	CASH ACCUMULATED (\$) IN 10 YEARS AFTER PAYING THE INITIAL COST DIFFERENCE	
				INITIAL	COST DIFFERENCE OVER CONVENTIONAL				
			(\$)	(\$)	(\$)	(%)			
Oil Furnace									
Standard	(Cdn Gal)	500							
+ Air Conditioner	(kWh)	1,586	768	69	3,200	63	2,000	2.42	
+ Hot Water Heater	(kWh)	5,986						46	
								10,233	
Electric Furnace*									
Standard	(kWh)	13,587							
+ Air Conditioning	(kWh)	1,586	931	63	4,100	21	900	1.48	
+ Hot Water Heater	(kWh)	5,986						75	
								8,505	
Gas Furnace									
Standard	(Therms)	773							
+ Air Conditioning	(kWh)	1,586	818	58	3,400	53	1,400	3.35	
+ Hot Water Heater	(Therms)	344						32	
								5,807	
Gas Furnace									
High Efficiency	(Therms)	487							
+ Air Conditioning	(kWh)	1,586	626	46	4,500	16	700	2.29	
+ Hot Water Heater	(Therms)	344						49	
								3,853	
Heat Pump - Air Source*									
All Electric	(kWh)	7,998							
+ Air Conditioning	(kWh)	1,586	685	50	4,500	16	700	2.29	
+ Hot Water Heater	(kWh)	5,986						49	
								3,853	
Water Source									
All Electric	(kWh)	4,852							
+ Air Conditioning	(kWh)	804	341						
+ Hot Water Heater	(kWh)	2,093							
								5,200	

* Includes 200 A Service Installation (\$1,100)

TABLE 1b

GROUND SOURCE SYSTEMS VS CONVENTIONAL SYSTEMS

HOMER MODEL NO. 1 INSTALLATION TYPE HU

PAGE 9

VARIOUS HEATING AND COOLING SYSTEMS	ENERGY ANALYSIS		COMPARED TO WATER SOURCE HEAT PUMPS		PAYBACK ANALYSIS	
	ENERGY CONSUMED	FIRST YEAR ENERGY COSTS (\$)	FIRST YEAR SAVINGS OVER CONVENTIONAL (\$)	INSTALLATION COSTS		CASH ACCUMULATED (\$) IN 10 YEARS AFTER PAYING THE INITIAL COST DIFFERENCE
				INITIAL (\$)	COST DIFFERENCE OVER CONVENTIONAL (\$)	
					YRAYS TO PAY BACK THE DIFFERENCE (\$)	RETURN ON INVESTMENT (%)
Oil Furnace						
Standard	(Gdn Gal)	500				
+ Air Conditioner	(kWh)	1,588	768	3,200	140	4,500
+ Hot Water Heater	(kWh)	5,986				
					4.93	20
						7,733
Electric Furnace*						
Standard	(kWh)	13,587				
+ Air Conditioning	(kWh)	931	590	4,300	79	3,600
+ Hot Water Heater	(kWh)	5,986				
					5.0	19
						5,805
Gas Furnace						
Standard	(Therms)	773				
+ Air Conditioning	(kWh)	1,588	477	3,400	127	4,300
+ Hot Water Heater	(Therms)	344				
					6.73	10
						1,307
Gas Furnace						
High Efficiency	(Therms)	487				
+ Air Conditioning	(kWh)	626	286	4,500	71	3,200
+ Hot Water Heater	(Therms)	344				
					7.88	6
						1,353
Heat Pump - Air Source*						
All Electric	(kWh)	7,998				
+ Air Conditioning	(kWh)	1,588	344	5,900	31	1,800
+ Hot Water Heater	(kWh)	5,986				
					4.4	23
						3,686
Water Source						
All Electric	(kWh)	4,852				
+ Air Conditioning	(kWh)	804		7,700		
+ Hot Water Heater	(kWh)	2,093				

* Includes 200 A Service Installation (\$1,100)

TABLE 1c

GROUND SOURCE SYSTEMS VS CONVENTIONAL SYSTEMS

HOME MODEL NO. 1

INSTALLATION TYPE V

PAGE 10

VARIOUS HEATING AND COOLING SYSTEMS	ENERGY ANALYSIS			COMPARED TO WATER SOURCE HEAT PUMPS			PAYBACK ANALYSIS		
	CONSUMED	FIRST YEAR ENERGY COSTS (\$)	FIRST YEAR SAVINGS OVER CONVENTIONAL (\$)	INITIAL COST (\$)	COST DIFFERENCE OVER CONVENTIONAL (\$)	YEARS TO PAY BACK THE DIFFERENCE (\$)	RETURN ON INVESTMENT	CASH ACCUMULATED (\$) IN 10 YEARS AFTER PAYING THE INITIAL COST DIFFERENCE	
Oil Furnace Standard + Air Conditioner + Hot Water Heater	(Cdn Gal) 500 1,588 5,986	1,109	768	69	3,200	213	6.65	11	5,411
Electric Furnace Standard + Air Conditioning + Hot Water Heater	(kWh) 13,997 1,588 5,986	931	888	63	4,360	133	7.69	9	3,785
Gas Furnace Standard + Air Conditioning + Hot Water Heater	(Therms) 773 1,588 344	818	477	58	3,400	194	9.11	2	1,007
Gas Furnace High Efficiency + Air Conditioning + Hot Water Heater	(Therms) 487 1,588 344	626	286	46	4,500	122	11.3	0	0
Heat Pump - Air Source* All Electric + Air Conditioning + Hot Water Heater	(kWh) 7,998 1,588 5,986	685	344	50	5,900	70	8.22	5	1,186
Water Source All Electric + Air Conditioning + Hot Water Heater	(kWh) 4,852 804 2,093	341			10,000				

* Includes 200 A Service Installation (\$1,100)

TABLE 2a

WATER SOURCE SYSTEMS VS CONVENTIONAL SYSTEMS

HOME MODEL NO. 2 INSTALLATION TYPE M

PAGE 11

VARIOUS HEATING AND COOLING SYSTEMS	ENERGY ANALYSIS		COMPARED TO WATER SOURCE HEAT PUMPS				PAYBACK ANALYSIS		
	FIRST YEAR ENERGY CONSUMED	FIRST YEAR ENERGY COSTS (\$)	FIRST YEAR SAVINGS OVER CONVENTIONAL		INSTALLATION COSTS		YEARS TO PAY BACK THE DIFFERENCE	RETURN ON INVESTMENT	CASH ACCUMULATED (\$) IN 10 YEARS AFTER PAYING THE INITIAL COST DIFFERENCE*
			(\$)	(%)	INITIAL	COST DIFFERENCE OVER CONVENTIONAL			
Oil Furnace									
Standard	(Cdn Gall)	2,500							
+ Air Conditioner	(kwh)	4,541	3,213	71	5,300	34	1,800	0.56	189
+ Hot Water Heater	(kwh)	11,373							49,413
Electric Furnace*									
Standard	(kwh)	67,997							
+ Air Conditioning	(kwh)	3,659	2,333	64	8,000	-11	-900	IMMEDIATE	37,177
+ Hot Water Heater	(kwh)	11,373							
Gas Furnace									
Standard	(Therms)	3,868							
+ Air Conditioning	(kwh)	3,197	1,870	59	5,500	29	1,600	0.96	127
+ Hot Water Heater	(Therms)	654							28,205
Gas Furnace									
High Efficiency	(Therms)	2,437							
+ Air Conditioning	(kwh)	2,239	911	41	6,500	9	600	0.66	162
+ Hot Water Heater	(Therms)	654							13,925
Heat Pump - Air Source*									
All Electric	(kwh)	39,995							
+ Air Conditioning	(kwh)	2,428	1,101	45	9,300	-31	-2,200	IMMEDIATE	17,540
+ Hot Water Heater	(kwh)	11,373							
Water Source									
All Electric	(kwh)	24,283							
+ Air Conditioning	(kwh)	1,905							
+ Hot Water Heater	(kwh)	3,977							7,100

* Includes 400 A Service Installation (\$2,500)

TABLE 2b

GROUND SOURCE SYSTEMS VS CONVENTIONAL SYSTEMS

HOME MODEL NO. 2 INSTALLATION TYPE H₂

PAGE 12

VARIOUS HEATING AND COOLING SYSTEMS	ENERGY ANALYSIS		COMPARED TO WATER SOURCE HEAT PUMPS			PATRICK ANALYSIS		
	ENERGY CONSUMED	FIRST YEAR ENERGY COSTS (\$)	FIRST YEAR SAVINGS OVER CONVENTIONAL		INITIAL COST (\$)	INSTALLATION COSTS		PATRICK ANALYSIS
			(\$)	(%)		COST DIFFERENCE OVER CONVENTIONAL	YAP BACK THE PAY BACK THE DIFFERENCE (%)	RETURN ON INVESTMENT IN 10 YEARS CASH ACCUMULATED (\$) AFTER PAYING THE INITIAL COST DIFFERENCE
Oil Furnace								
Standard	(Cdn Gal)	2,500						
+ Air Conditioner	(kWh)	3,810	4,541	71	5,300	130	6,900	55
+ Hot Water Heater	(kWh)	11,373					2.04	44,313
Electric Furnace*								
Standard	(kWh)	67,997						
+ Air Conditioning	(kWh)	3,810	3,660	64	8,000	53	4,200	65
+ Hot Water Heater	(kWh)	11,373					1.73	32,978
Gas Furnace								
Standard	(Therms)	3,868						
+ Air Conditioning	(kWh)	3,810	3,197	59	5,500	120	6,700	34
+ Hot Water Heater	(Therms)	654					3.20	23,105
Gas Furnace								
High Efficiency	(Therms)	2,437						
+ Air Conditioning	(kWh)	3,810	2,239	41	6,500	88	5,700	18
+ Hot Water Heater	(Therms)	654					5.09	8,825
Heat Pump - Air Source*								
All Electric	(kWh)	39,995						
+ Air Conditioning	(kWh)	3,810	2,239	45	9,300	31	2,900	46
+ Hot Water Heater	(kWh)	11,373					2.44	14,640
Water Source								
All Electric	(kWh)	24,283						
+ Air Conditioning	(kWh)	1,905						
+ Hot Water Heater	(kWh)	3,977						

* Includes 400 A Service Installation (\$2,500)

TABLE 2c

GROUND SOURCE SYSTEMS VS CONVENTIONAL SYSTEMS

HOME MODEL NO. 2 INSTALLATION TYPE V

PAGE 11

VARIOUS HEATING AND COOLING SYSTEMS	ENERGY ANALYSIS		COMPARED TO WATER SOURCE HEAT PUMPS				PAYBACK ANALYSIS		
	ENERGY CONSUMED	FIRST YEAR ENERGY COSTS (\$)	FIRST YEAR SAVINGS OVER CONVENTIONAL		INSTALLATION COSTS		YEARS TO PAY BACK THE DIFFERENCE (\$)	INVESTMENT ON INITIAL COST DIFFERENCE	CASH ACCUMULATED (\$) IN 10 YEARS AFTER PAYING THE INITIAL COST DIFFERENCE
			(\$)	(%)	INITIAL COST (\$)	OVER CONVENTIONAL COST DIFFERENCE (\$)			
Oil Furnace									
Standard	(Cdn Gal)	2,500							
+ Air Conditioning	(kwh)	4,541	3,213	71	5,300	192	10,200	2.89	38
+ Hot Water Heater	(kwh)	11,373							41,013
Electric Furnace*									
Standard	(kwh)	67,997							
+ Air Conditioning	(kwh)	3,660	2,333	64	8,000	94	7,500	2.92	38
+ Hot Water Heater	(kwh)	11,373							29,677
Gas Furnace									
Standard	(Therma)	3,868							
+ Air Conditioning	(kwh)	3,197	1,870	59	5,500	182	10,000	4.48	22
+ Hot Water Heater	(Therma)	654							19,805
Gas Furnace									
High Efficiency	(Therma)	2,437							
+ Air Conditioning	(kwh)	2,238	911	41	6,500	139	9,000	7.20	8
+ Hot Water Heater	(Therma)	654							5,525
Heat Pump - Air Source*									
All Electric	(kwh)	39,995							
+ Air Conditioning	(kwh)	2,428	1,101	45	9,300	66	6,200	4.68	21
+ Hot Water Heater	(kwh)	11,373							11,340
Water Source									
All Electric	(kwh)	24,283							
+ Air Conditioning	(kwh)	1,327			15,500				
+ Hot Water Heater	(kwh)	3,977							

* Includes 400 A Service Installation (\$2,500)

*COMPARISON SUMMARY: GROUND AND WATER SOURCE VS CONVENTIONAL SYSTEMS

TABLE 3

VARIOUS HEATING AND COOLING SYSTEMS	GROUND AND WATER SOURCE INSTALLATION TYPES	SMALLER HOME - MODEL NO. 1					LARGER HOME - MODEL NO. 2				
		INITIAL COST DIFFERENCE (b)	FIRST YEAR SAVINGS (b)	PAYBACK IN YEARS	RETURN ON INVESTMENT (b)	ACCUMULATED CASH IN 10 YEARS (\$)	INITIAL COST DIFFERENCE (b)	FIRST YEAR SAVINGS (b)	PAYBACK IN YEARS	RETURN ON INVESTMENT (b)	ACCUMULATED CASH IN 10 YEARS (\$)
Oil Furnace + Air Conditioner + Hot Water Heater	W	63	69	2.42	46	10,233	34	71	0.56	189	49,413
	RV	140	69	4.83	20	7,733	130	71	2.04	55	44,113
	V	213	69	6.65	11	5,433	192	71	2.89	38	41,013
Electric Furnace + Air Conditioning + Hot Water Heater	W	21	63	1.48	75	8,505	-11	64	IMMEDIATE	HIGH	37,177
	RV	79	63	5.00	19	5,805	53	64	1.73	65	32,979
	V	133	63	7.09	9	3,705	94	64	2.92	38	29,677
Gas Furnace Standard + Air Conditioning + Hot Water Heater	W	53	58	3.35	32	5,807	29	59	0.86	127	28,205
	RV	127	58	6.73	10	3,107	120	59	3.20	34	23,105
	V	194	58	9.11	2	1,007	182	59	4.48	22	19,805
Gas Furnace High Efficiency + Air Conditioning + Hot Water Heater	W	16	46	2.29	49	3,853	9	41	0.66	162	13,925
	RV	71	46	7.88	6	1,353	88	41	5.09	18	8,825
	V	122	46	11.3	0	0	139	41	7.20	8	5,525
Heat Pump - Air All Electric + Air Conditioning + Hot Water Heater	W	-13	50	IMMEDIATE	HIGH	6,185	-31	45	IMMEDIATE	HIGH	17,540
	RV	31	50	4.4	23	3,686	31	45	2.44	46	14,640
	V	70	50	8.22	5	1,386	66	45	4.48	21	11,140
Average		-	88	5.38	27	4,533	75	56	7.58	68	25,165

* Data extracted from Tables 1a, 1b, 1c, 2a, 2b, 2c

TABLE 5

HEATING AND COOLING SYSTEMS' DESCRIPTION

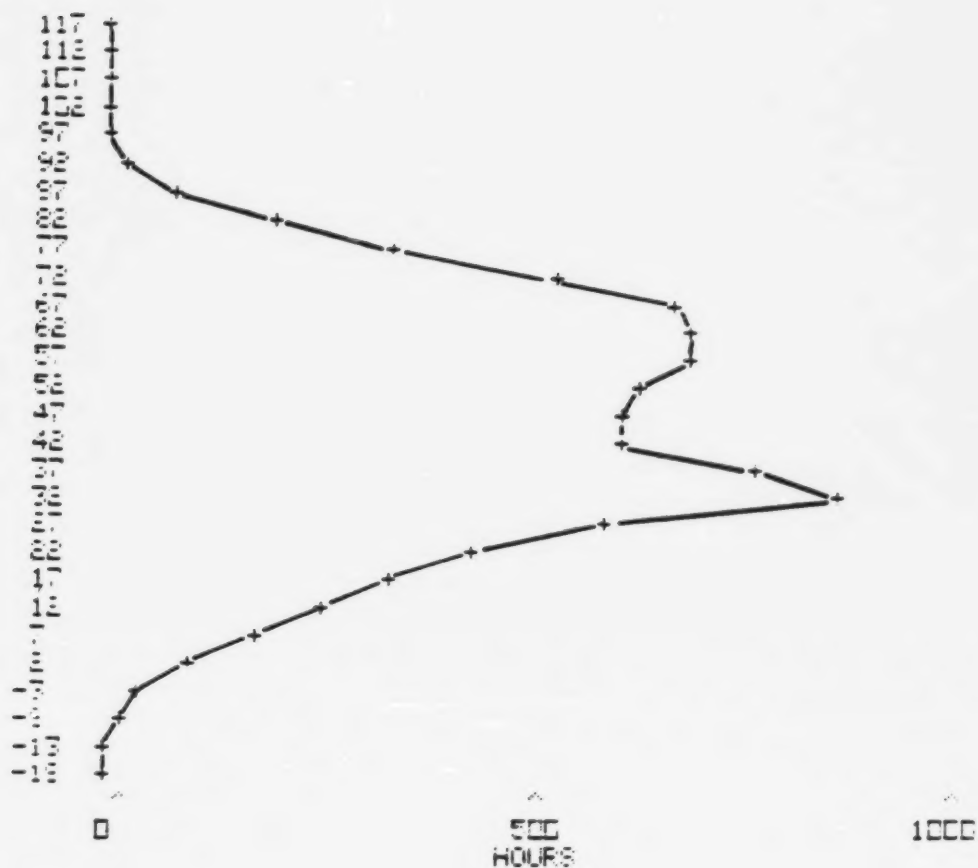
<u>HEATING AND COOLING SYSTEM</u>	<u>SEASONAL PERFORMANCE</u>	<u>SYSTEM COST MODEL NO. 1 \$</u>	<u>SYSTEM COST MODEL NO. 2 \$</u>
Oil Furnace (No tank-worth \$350) Air Conditioner	EFP = 55% EER = 8.0	3,200	5,300
Electric Furnace (Service incl. Air Conditioner worth \$1100-2500)	EFP = 100% EER = 8.0	4,300	8,000
Gas Furnace-STD (No liner-worth \$350) Air Conditioner	EFP = 60% EER = 8.0	3,400	5,500
Gas Furnace (High-efficiency) Air Conditioner	EFP = 95% EER = 8.0	4,500	6,500
Heat Pump-Air (Service incl. All Electric worth \$1100-2500)	SPF = 1.7 EER = 8.0	5,900	9,300
Water Source-Type "W" All Electric Air Conditioner (De-superheater incl.)	SPF = 2.8 EER = 16.0	5,200	7,100
Ground Source-Type "HV" All Electric Air Conditioner (De-superheater incl.)	SPF = 2.8 EER = 16.0	7,700	12,200
Ground Source-Type "V" All Electric Air Conditioner (De-superheater incl.)	SPF = 2.8 EER = 16.0	10,000	15,500

TABLE 6
WEATHER DATA

City	Degree Hours			Precipitation (Inches)	Relative Humidity (%)	Average Winter Temp (F)	Heating Hours (Below 42 F)
	Total Hours	Below 42 F					
		Hours	%				
Halifax	190,177	142,170	75	41	79	33.6	4,105
Montreal	198,033	156,317	83	24	71	32.7	4,087
Toronto	184,663	148,857	81	19	75	35.5	4,005
Winnipeg	259,548	229,573	88	10	74	23.1	4,726
Calgary	234,416	191,038	82	7	64	28.7	4,636
Victoria	138,650	88,776	64	29	82	44.2	2,290

Source: "Factors Affecting Seasonal Performance of Heat Pumps in Canada"

TABLE 7
TORONTO, ONTARIO
HISTOGRAM OF TEMPERATURES



TEMP	HOURS	TEMP	HOURS	TEMP	HOURS	TEMP	HOURS
117	0	82	194	47	623	12	254
112	0	77	346	42	619	7	174
107	0	72	532	37	787	2	102
102	0	67	681	32	876	-3	43
97	0	62	690	27	609	-8	18
92	17	57	701	22	430	-13	0
87	83	52	644	17	341	-18	0

CLOUD COVER (%) = 52.6

DAILY TEMPERATURE RANGE = 22

HEATING COST FOR VARIOUS HEATING SYSTEMS

SYSTEM CHOICE	HALIFAX	MONTREAL	TORONTO	WINNIPEG	CALGARY	VICTORIA
	SYSTEM	COST (\$)	SYSTEM	COST (\$)	SYSTEM	COST (\$)
1	Ground Source Heat Pump	567	Ground Source Heat Pump	382	Gas - High Efficiency	359
2	All Electric Heat Pump	862	Gas- High Efficiency	550	Gas- Mid Efficiency	446
3	Oil & Heat Pump Add On	880	All Electric Heat Pump	618	Ground Source Heat Pump	484
4	Elec. & Heat Pump Add On	937	Gas & Heat Pump Add On	632	Gas & Heat Pump Add On	547
5	Oil Furnace	1280	Elec. & Heat Pump Add On	682	Gas- Standard Eff.	557
6	Electric Furnace	1531	Gas- Mid Efficiency	688	All Electric Heat Pump	858
7			Oil & Heat Pump Add On	750	Oil & Heat Pump Add On	903
8			Gas- Standard Eff.	852	Elec. & Heat Pump Add On	914
9			Electric Furnace	1032	Electric Furnace	1106
10			Oil Furnace	1265	Oil Furnace	1361

The heat pump capacity used for all 6 cities was 24,000 BTU/h.

Furnace seasonal efficiencies: (a) standard oil furnace 55% (b) electric furnace 100% (c) gas furnace: 1. standard 60%, 2. medium 75%, 3. high 91%

(d) air source heat pump SPP = 1.7 (e) ground source heat pump SPP = 2.7.

* Table reproduced from a comprehensive study of heating systems in Canada, a study by Gino DiRezze of Villeneuve Heating, entitled "Factors Affecting Seasonal Performance of Heat Pumps in Canada".

The paper was presented at the 7th Heat Pump Technology Conference, Oklahoma State University, on October 15 & 16, 1984, at Stillwater, Oklahoma.

TABLE 9

CONVERSIONS

1 CDN GALLON = 1 UK GALLON = 1.21 USA GALLONS = 4.5 LITRES
1 CDN GALLON = 168,000 BTU (NO. 2 OIL)
1 M³ = 220 CDN GALLONS
1 THERM = 100 CU FT OF NATURAL GAS
1 THERM = 9.29 CU METERS
1 THERM = 10,000 BTU
1 KW = 3,413 BTU

1 SQ METER = 10.76 SQ FT
2,000 SQ FT = 186 SQ METERS
5,000 SQ FT = 465 SQ METERS
1 CDN DOLLAR = \$0.76 US DOLLAR

FUEL COSTS USED

HYDRO	\$0.044/KWH
GAS	\$0.67/THERM
OIL	\$1.55/CDN GALLON \$1.29/US GALLON \$0.34/L

PAYBACK ASSUMPTIONS

1. ALL FUELS TO RISE 10% PER YEAR FOR THE NEXT 10 YEARS.
2. CALCULATIONS MADE OVER 10-YEAR PERIOD.
3. NO ALLOWANCE MADE FOR COST OF MONEY INVESTED.
4. PRESENT WORTH (%) = RETURN ON INVESTMENT (%)

APPROXIMATE STRUCTURE DESCRIPTION

Cooling Size 2 1/2 tons (30,000 BTUH)
 Heating Size 20 kW (68,000 BTUH)
 Yearly Energy Use 92,823 BTUH
 Approx. Sq. Ft. House Oil - Old 1800
 - New 2500
 (Based on 600 sq. ft./ton to 1000 sq. ft./ton)

FUEL USED	OIL (Gallons)	ELECTRIC (kWh)	GAS STD (Therms)	HEAT PUMP ELECTRIC (kWh)	GAS HIGH (Therms)	GROUND SOURCE (kWh)
Consumption	1,000	27,197	1,547	15,998	975	9,713
Cost Factor	1.0	0.8	0.71	0.47	0.44	0.28
1984	\$ 1,470	1,170	1,037	688	653	418
1985	1,646	1,310	1,161	771	731	468
1986	1,844	1,468	1,301	863	819	524
1987	2,065	1,644	1,457	967	917	587
1988	2,313	1,841	1,632	1,083	1,028	658
1989	2,591	2,062	1,828	1,213	1,151	737
5-YEAR TOTAL	10,459	8,325	7,379	4,897	4,646	2,974
1990	2,902	2,309	2,047	1,358	1,289	825
1991	3,250	2,587	2,292	1,522	1,444	924
1992	3,640	2,897	2,568	1,704	1,617	1,035
1993	4,076	3,245	2,876	1,909	1,811	1,159
1994	4,566	3,634	3,221	2,138	2,028	1,298
10-YEAR TOTAL	28,892	22,994	20,379	13,533	12,831	8,215

FUEL PRICES IN TORONTO

Based on January, 1984.

hydro \$0.043 per kWh
 gas \$0.67 per 100 cu. ft.
 (therms)
 oil \$1.47 per gal.

FURNACE EFFICIENCIES - SEASONAL

oil 55%
 standard gas 60%
 high eff. gas 95%
 air source heat pumps SPF = 1.7
 ground source heat pumps SPF = 2.8

12% yearly
 increase on
 all fuels.

BIBLIOGRAPHY

1. BOSE, J.E., "Water Source HVAC Design Manual", School of Technology, Oklahoma State University, 1982.
2. DIREZZE, U.G., "Factors Affecting Seasonal Performance of Heat Pumps in Canada", The 7th Heat Pump Technology Conference, Oklahoma State University, Tulsa, Oklahoma, October, 1984.

SPEAKING NOTES FOR
G. VANDERVAART
KOOL-FIRE
NIAGARA FALLS, ONTARIO

GROUND SOURCE HEAT PUMPS
- OPTIONS, IMPLEMENTATION
AND STRATEGIES

AIRPORT HOLIDAY INN
970 DIXON ROAD
FIESTA BALLROOM

JANUARY 10, 1985
3:30 P.M.

G. Vandervaat

Gerry Vandervaat is President of Home Comfort Control Systems, of Niagara Falls---developer of "Kool-Fire" gas assisted heat pumps. Born in Holland, he has been active in the air conditioning and heating business in Canada for many years.

DESCRIPTION

This unit could be described as a gas assisted split-system heat pump. It is really a condensing gas furnace and a heat pump combined into one system. It has an outdoor section consisting of a blower and a heat exchanger ("A"-coil) mounted in an enclosure with a gas burner below the heat exchanger. The indoor section consists of a heat exchanger and an air handler. The compressor and associated controls can be located either outdoors or indoors, depending on the particular version chosen.

The system operates as a central air-conditioner in summer. In winter, it cycles as an ordinary air-source heat pump to maintain indoor temperature at a set value. If outdoor conditions become so cold that the heat pump is unable to fully heat the house, a second stage on the indoor thermostat activates the gas burner under the outdoor coil. The outdoor blower stops, but the compressor continues to run to transfer the flame's heat indoors. Most of the higher heat of combustion of the gas can be recovered since the warm flue gases condense as they contact the relatively cool outdoor coil.

Heavy frost on the heat pump's outdoor coil can also activate the gas burner. This is done through the operation of a simple air flow sensing switch on the outdoor unit. The gas flame defrosts the unit without any need for the usual reverse cycle defrost.

A Kool-Fire gas burning cycle always terminates when the house need for heat is satisfied. The Kool-Fire Model LTH then reverts to heat pump mode for the next operating cycle, thus maximizing the efficiency of the system's operation, and keeping fuel consumption to a minimum.

EFFICIENCY

When in the gas-burning mode, the overall efficiency averages about 95 per cent. In the heat pump mode, the efficiency is claimed to exceed 240 per cent at 8.3°C (47°F) and 160 per cent at -8.3°C (17°F). The Kool-Fire can burn either natural gas or propane.

BENEFITS

The Kool-Fire unit should be able to provide low-cost heating and cooling. Model LTH utilizes the advantages of the air-source heat pump whenever possible and uses relatively inexpensive gas energy in the coldest weather.

A 100 amp residential service entrance will be adequate in many cases since no electric resistance heat is required.

Since no gas is burned indoors, a flue or chimney is not required. The unique gas fired defrost on Model LTH eliminates the inefficiencies and stresses associated with reverse cycle defrosting.

The complete unit is put together from "off-the-shelf" components. The manufacturer claims nothing is "made-to-order". Thus, replacement parts are readily obtainable.

The compressor is guaranteed for 10 years.

COSTS

A conversion using an existing furnace blower and ductwork will cost around \$3800 - \$4500 on average. A new home installation will run about \$6000-\$7000 including ductwork, depending on size and design.

APPROVALS

Kool-Fire units are CGA, CSA and AGA approved.

COMMENTS

Gas consumption on the LTH model should be low enough to make propane bottles an attractive alternative in areas where gas lines are unavailable.

A line of roof top units is now in production for use in commercial situations.

SPEAKING NOTES FOR
A.C. BIERBAUM, CHIEF ENGINEER
IOWA ASSOCIATION OF ELECTRIC COOPERATIVES
IOWA, U.S.A.

OPERATING PERFORMANCE
OF
IOWA REC MEMBER
GROUNDWATER HEAT PUMP INSTALLATIONS

AIRPORT HOLIDAY INN
970 DIXON ROAD
FIESTA BALLROOM

JANUARY 10, 1985
3:30 P.M.

A.C. Bierbaum

Alvin Bierbaum is Chief Engineer of the Iowa Association of Electric Co-operatives. With a B.Sc. in Engineering Operations from Iowa State University, and a M.B.A. from Drake University, he supplies technical services to 52 utilities in Iowa. He was Senior Electrical Engineer for Iowa Power and Light Company, in distribution design and electric system planning. He has produced a "Selection and Application Handbook" on groundwater heat pumps.

GROUNDWATER HEAT PUMP INSTALLATION NO. 1

Mr. & Mrs. Lorin Peterson
Rural Route
Stanton, Iowa

Family: 4 with 2 small children.

Utility: Nyman Electric Cooperative
Stanton, Iowa.

Heat System: 3-ton Command/AIRE unit with 14 kW
auxiliary plenum heater.

Heating Source: Horizontal closed loop heat pump with
1,100' of 2" polybutylene pipe buried
in ground; filled with water with a 25%
solution of propylene glycol
anti-freeze solution.

Circulating Pump: 2 - 1/2 HP Grund FOS circulating pumps.

House: 1,768 square feet with full basement
built in 1982; R-42 attic insulation;
R-28 sidewall insulation; triple glazed
windows.

1982-83 Heating Usage: 7,071 kWh's (\$390).

Domestic Hot Water
Generator: A compressor desuperheater is used
which is metered separately. Prior to
installation, the family averaged 700
kWh's per month for water heating. The
desuperheater reduced this to 400 kWh's
which saved approximately 300 kWh's per
month or \$15 per month.

Comments: Due to an improper setting on the
incoming water temperature cutoff
control, auxiliary heat was used during
the last two weeks of December and the
first week of January. This added
approximately 1,300 kWh's additional
usage during the 1982-83 heating season.

Purging the system of air during
start-up was a problem until a large
1 hp centrifugal pump was temporarily
used to clean out the loop.

GROUNDWATER HEAT PUMP INSTALLATION NO. 2

Mr. & Mrs. Robert Walton
Rural Route
Dubuque, Iowa

Family: 4 with 2 small children.

Utility: Maquoketa Valley REC
Anamosa, Iowa.

Heat System: 2 - 2.3 Comfort/AIRE units with 20 kW
auxiliary duct heaters.

Heating Source: Vertical closed loop heat pump using a
300', 6" diameter well. The well has
pumping capacity of 90 gallons per
minute and a static water level of
135'. Total loop length is
approximately 700' with 1-1/2" plastic
pipe used from GWHP to the well. A
finned tube copper heat exchanger,
approximately 50' long and 1-1/2" in
diameter, was used in the well. The
loop operates under slight pressure.

Circulating Pump: 1/3 HP centrifugal.

House: 2,686 square feet with full basement
built in 1980; R-40 attic insulation;
R-20 sidewall insulation; double glazed
windows.

1981/82 Heating Usage: 8,286 kWh (\$414)

1982/83 Heating and
Cooling Usage*: 9,814 kWh (\$500)
(*March 1982 -
April 30, 1983.)

Comments: Estimated air conditioning usage was
2,000 kWh. Loop water temperature
(5/1/83) -- 46 degrees out and
41 degrees in. Without a significant
water flow in the well, this system
would not have operated satisfactorily
due to probable water freeze up. A
compressor desuperheater was in use.
Domestic hot water heating usage was
not metered.

GROUNDWATER HEAT PUMP INSTALLATION NO. 3

Mr. & Mrs. Verl Arnold
Bloomfield, Iowa

Family: Two.

Utility: Bloomfield Municipal.

Heat System: 2-1/2 ton Comfort/AIRE unit with 15 kW auxiliary duct heaters.

Heating Source: Vertical closed loop heat pump using 4 - 100' wells, 800' - 1-1/2", 200 psi PVC pipe installed in series. The wells were drilled with a do-it-yourself "deep rock" well drilling machine. The loop temperature dropped to 31 degrees in February. The loop temperature on April 15 was 47 degrees.

Circulating Pump: 1/4 HP Centrifugal.

House: 1,100 square feet with full basement built in 1960; R-24 attic insulation; R-10 sidewall insulation; double glazed windows.

1982-83 Heating Usage: 5,476 kWh (\$301).

Domestic Hot Water Heating: None.

Comments: One of the loops sprung a leak. Approximately 2 gallons per day make up. The loop is not pressurized.

GROUNDWATER HEAT PUMP INSTALLATION NO. 4

Mr. & Mrs. Dean Armstutz
Rural Route
Bloomfield, Iowa

Family: 4 with 2 small children.

Utility: S.E. Iowa Co-op Electric
Mt. Pleasant, Iowa.

Heat System: 1 - 3-1/2 ton Comfort/AIRE unit with
20 kW auxiliary plenum heater.

Heating Source: Horizontal closed loop heat pump with
2,100' of 1-1/2", 200 psi, PVC pipe
buried 8-10' deep -- filled with water
-- no antifreeze.

Circulating Pump: 1/3 HP Centrifugal.

House: 2,640 square feet with full basement
built in 1980; R-40 attic insulation;
R-28 sidewall insulation; 50% triple
glazed and the remainder double glazed
windows.

Heating Usage:

1980-81	5,450 kWh
1981-82	6,257 kWh
1982-83	4,860 kWh.

Domestic Hot Water Heating: None.

Comments: The backup resistance heating was never
operated. kWh consumption included
water pumping. The loop is not
pressurized. Air conditioning is
accomplished by circulating the loop
water through a car radiator placed in
front of the GWHP heat exchanger fan.

GROUNDWATER HEAT PUMP INSTALLATION NO. 5

Mr. & Mrs. James Preston
Rural Route
Swea City, Iowa

Family: 3 with 1 teenager.

Utility:

Heat System: 4-ton TETCO unit with two 10 kw
auxiliary heaters.

Heating Source: Domestic water well for household and
livestock use. Water is discharged
into farm drainage tile.

House: 1,800 square feet with full basement
built in late 1940's; R-24 attic
insulation; R-12 sidewall insulation;
double glazed windows.

1982-83 Heating Usage: 9,800 kWh.

Domestic Hot Water
Heating: None.

Comments: During the months of January, February
and March, resistance back-up heat was
used quite often due to water supply
problems to the GWHP. In looking at
the mag. tape printout, it appears that
resistance heat was on for over
100 hours during the season.

GROUNDWATER HEAT PUMP INSTALLATION NO. 6

Mr. & Mrs. Richard Stille
Rural Route
Swaledale, Iowa

Family: Two.

Utility: Franklin REC
Hampton, Iowa.

Heat System: 4-ton TETCO unit with two 10 kW
auxiliary duct heaters - absorbtive
cooling.

Heating Source: Domestic water well also used for
household purposes. Water is
discharged into field drainage tile.

House: 1,400 square feet with full basement
built in 1981; R-42 attic insulation;
R-28 sidewall insulation; triple glazed
windows.

1982-83 Heating Usage: 3,400 kWh (\$172)
1982 Air Conditioning*: 240 kWh (\$12).

Domestic Hot Water
Heating: None.

Comments: The TETCO unit does not use a freon
compressor in the air conditioning
mode. The summer energy costs shown
are for only the water pump and heat
exchanger fan. During operation, the
TETCO unit uses approximately 4 gallons
of water per minute. Maximum water
usage measured last winter was
1,500 gallons per day.

GROUNDWATER HEAT PUMP INSTALLATION NO. 7

Mr. & Mrs. Ron Zickenfoose
Rural Route
Sheffield, Iowa

Family: 4 with 2 small children.

Utility: Franklin REC
Hampton, Iowa.

Heat System: 2 - 2.4-ton Carrier units with 20 kw
auxiliary duct heaters.

Heating Source: Domestic water well also used for
household purposes. Water is
discharged into field drainage tile.

House: 3,000 square feet with full basement
built in 1982; R-42 attic insulation;
R-28 sidewall insulation; triple glazed
windows.

1982-83 Heating Usage: 2,901 kWh (\$160).

Domestic Hot Water
Heating: Used but not metered.

Comments: 1982 summer air conditioning was
1,577 kWh.

GROUNDWATER HEAT PUMP INSTALLATION NO. 8

Mr. & Mrs. Harold O'Neill
Rural Route
Logan, Iowa

Family: Two.

Utility: Harrison County REC
Woodbine, Iowa.

Heat System: 4-ton TETCO unit with existing oil
furnace as backup.

House: 1,080 square feet with full basement;
R-15 attic insulation; R-6 sidewall
insulation; double glazed windows.

Heating Usage
8/81-4/30/83: 10,143 kWh (\$601)
(Covers two heating
seasons and one
cooling season.)

Domestic Hot Water
Heating: None.

Comments: Using No. 2 fuel oil, the annual
heating bill in 1980-82 was \$1,260.

GROUNDWATER HEAT PUMP INSTALLATION NO. 9

Mr. & Mrs. Harold Heimstra
Rural Route
Kingsley, Iowa

Family: Two.

Utility: Plymouth REC
Le Mars, Iowa.

Heat System: 4.6-ton Tempmaster unit with 20 kW
auxiliary duct heaters.

Heating Source: Domestic water well also used for
household purposes. Water is
discharged into a second well located
100' away.

House: 1,856 square feet with full basement;
built in 1982; R-42 ceiling insulation;
R-28 sidewall insulation; triple glazed
windows.

Heating Usage: 3,545 kWh (\$195).

Domestic Hot Water
Heating: Used but not separately metered.

Comments: Incoming water temperature for a 52'
well - 52 degrees; outgoing temperature
- 44 degrees.

GROUNDWATER HEAT PUMP INSTALLATION NO. 10

Mr. & Mrs. Bert Hansen
Rural Route
Onawa, Iowa

Family: Two.

Utility: Monona REC
Onawa, Iowa.

Heat System: 4-ton TETCO unit - absorbtive cooling.

Heating Source: Domestic water well also used for household purposes. Water is discharged into a second well. Missouri river bottom area -- ample water supply from shallow wells.

House: 1,600 square feet with full basement; well insulated.

1982-83 Heating Usage: 3,066 kWh compressor
495 kWh well pump (estimated)
568 kWh heat exchanger fan
4,129 kWh (\$248).

Comments: Supply and return well approximately 100' deep - 2" diameter.

GROUNDWATER HEAT PUMP INSTALLATION NO. 11

Mr. & Mrs. Dick Ping
Rural Route
Onawa, Iowa

Family: Two.

Utility: Onawa Municipal
Onawa, Iowa.

Heat System: 4-ton TETCO unit - absorbtive cooling.

Heating Source: Shallow well in back yard with return
water discharge into city storm sewer.

House: 1,900 square feet with full basement.

1982-83 Heating Usage: 3,317 kWh (\$188).

Comments: 100' deep, 2" diameter well using a
1 hp pump and pressure tank -- 10',
40-slot Florida Johnson well screen.

GROUNDWATER HEAT PUMP INSTALLATION NO. 12

Mr. & Mrs. Everett Epperson
Onawa, Iowa

Family: Two.

Utility: Onawa Municipal
Onawa, Iowa.

Heat System: 4-ton TETCO unit - absorbtive cooling.

Heating Source: Shallow well in back yard with return
water discharge into return well
approximately 100' away.

House: 1,340 square feet with full basement.

1982-83 Heating Usage: 1,893 kWh compressor
236 kWh well pump
258 kWh heat exchanger fan
2,287 kWh (\$119).

Comments: Both wells are approximately 100' deep,
2" diameter. Source well has a 10'
screen; return well has a 20' screen.

GROUNDWATER HEAT PUMP INSTALLATION NO. 13

Mr. & Mrs. Kenneth Richardson
Onawa, Iowa

Family: Three.

Utility: Onawa Municipal
Onawa, Iowa.

Heat System: 4-ton TETCO unit.

Heating Source: Shallow well in back yard with return
water discharge into return well.

House: 2,400 square feet with full basement.

1982-83 Heating Usage: 3,518 kWh compressor
495 kWh well pump
501 kWh heat exchanger fan
4,514 kWh (\$248).

Comments: 2 - 180' deep, 2" diameter wells.
Source well has a 10', 40-slot screen;
return well has a 20', 40-slot Florida
Johnson screen.

SPEAKING NOTES FOR
D.B. MACCARTHY
VICE-PRESIDENT MARKETING
ONTARIO HYDRO
TORONTO, ONTARIO

GROUND SOURCE HEAT PUMP WORKSHOP
CLOSING REMARKS

AIRPORT HOLIDAY INN
970 DIXON ROAD
FIESTA BALLROOM

JANUARY 10, 1985
3:30 P.M.

D.B. MacCarthy

Dane MacCarthy is Vice President of Marketing of Ontario Hydro, with an honors B.A. degree in Business Administration. He joined Hydro with interests in personnel areas, labor relations and financial forecasting, moving to private industry and returning later to Hydro as Vice President of corporate relations.

I'm very pleased to have the opportunity to speak, however briefly, to such an innovative group. Today, you've taken a look at the potential benefits of Ground Source Heat Pumps for Ontario. These benefits help both the electrical utility through reduced winter peaks and our customers who get low cost efficient heating.

We are supportive of this technology and others that have the potential for saving energy and building load. This support fulfills our goal of helping our customers make the wisest use of our product.

Perhaps one of the biggest deterrents in Ground Source Heat Pump Applications is the need for capital investment to buy the equipment that will then save money. Speakers have stressed that this technology is in use in many nations such as the United States, Sweden, other European countries and our neighbouring province, Quebec.

It must be kept in mind that ground source heat pumps provide advantages and efficiencies that no other space conditioning system can offer. Payback on this investment may be better than initially expected when you consider product quality, equipment life and the special value of your energy savings which are in after-tax dollars.

Ontario Hydro is interested in further applications of ground source heat pumps. You may have met and talked to some of our staff today about residential and commercial applications. If you would like to discuss the relevance of some of today's presentations to your business, please call the Hydro representative located in your area. We would be pleased to provide any information or advice we can.

Heat pumps today are the result of many years of research and experience gathered around the world. Today's heat pumps work well in our Province for heating and cooling buildings and homes. They represent the best alternative for many people in the choice of their heating system. And ground source heat pumps are the most efficient heat pumps of all. We installed our first one in 1949. Today's improvements in drilling and piping now present us with practical systems that provide heating at less cost than any other means except burning free wood!

On closing, I would like to give special thanks to our speakers and panelists, many of whom have travelled great distances to participate. To our guests, I hope you have had a stimulating day and that you will leave this workshop with some new contacts to follow up and some new ideas on how heat pumps can play a greater role in meeting our Province's energy needs and securing a stable energy future.

Thank you for attending and have a safe journey home.

FOR EXTRA COPIES
OR NAMES AND ADDRESSES OF ATTENDEES

PLEASE CONTACT

PEGGY KURTIN
PUBLIC AFFAIRS OFFICER
COMMUNICATIONS SERVICES BRANCH
MINISTRY OF ENERGY
56 WELLESLEY STREET WEST
TORONTO, ONTARIO
M7A 2B7
(416) 965-1563